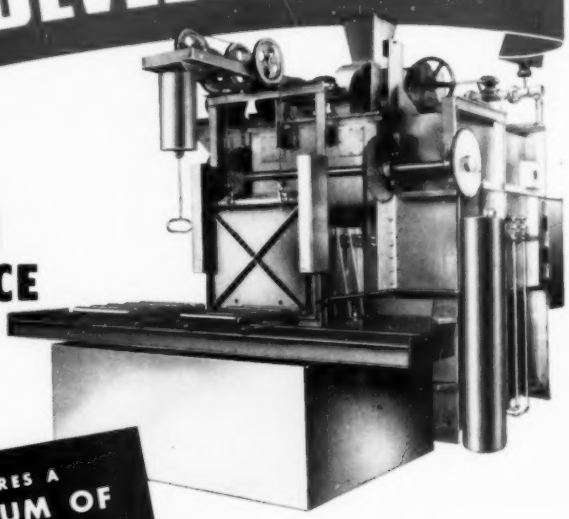
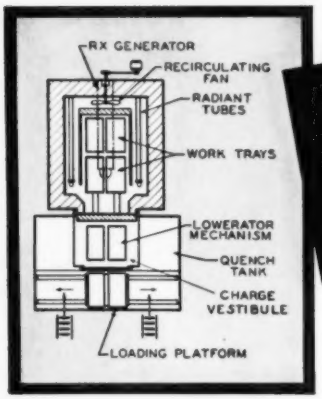
NOVEMBER 1949

A New AND IMPORTANT DEVELOPMENT

'Surface' HIGH PRODUCTION BATCH-TYPE FURNACE

***WITH BUILT-IN RX ATMOSPHERE GENERATOR**





REQUIRES A MINIMUM OF CAPITAL INVESTMENT PER POUND OF CAPACITY

DESIGNED FOR GREATER ECONOMY OF PRODUCTION

'Surface' researchers and engineers have combined all the time-proven features of furnace design into a unit that meets all the requirements for LOW COST, HIGH PRODUCTION of heat treated pieces.

Investigate its Cost Reducing Possibilities for your plant — Today! There is no obligation.

*Optional

★ **HIGH-RATE BATCH PRODUCTION** . . . Heats a gross load up to 200 lbs. per hr. per sq. ft. of hearth area, depending upon work and type of loading. Gross charge capacity of furnace up to 2500 lbs.

★ **LOW COST** . . . minimum investment for each pound of capacity. Light case cyaniding can be done for less than one-half cent per pound of work, exclusive of burden and fixed charge.

★ **EXTREME FLEXIBILITY** . . . especially adaptable to *Gas Carburizing, Carbon Restoration (Skin Recovery), Dry (gas) Cyaniding, Homogeneous Carburization, Clean Hardening, and for General Heat Treating.* Recommended for miscellaneous parts such as bolts, screws, fittings, etc., and straight shafts up to 12-13 inches long.

★ **'SURFACE' RADIANT TUBE HEATING** . . . with baffle between the work and the tubes.

★ **FASTER HEATING** . . . fan is used to circulate the heated prepared gas atmosphere around the work to secure a higher rate of heating and improve contact with the load.

★ **BUILT-IN 'SURFACE' ATMOSPHERE GENERATOR** . . . eliminates the need for an external generator, resulting in fuel and floor space economies.

★ **LOADING AND UNLOADING MECHANISM** . . . consists of two alloy screws to move loaded trays in and out of furnace. Furnace holds four trays at a time.

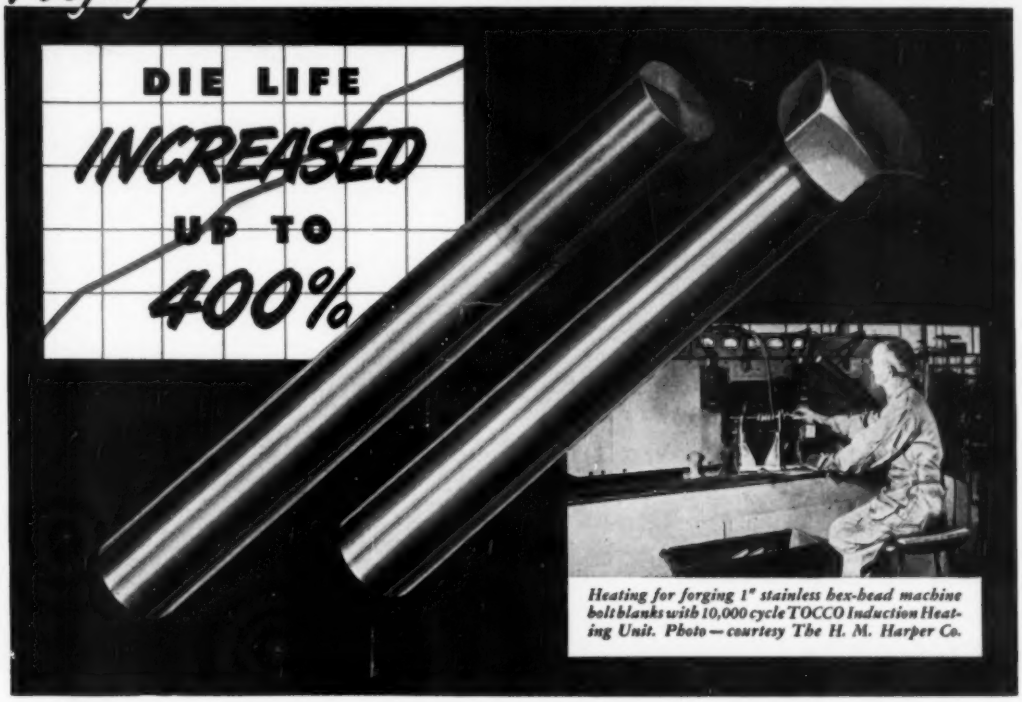
★ **AIR COOLING OF WORK** . . . can be done in the charge vestibule, or—

★ **LIQUID QUENCHING** . . . a lowerator mechanism provides means for oil quenching loaded trays in quench tank built adjacent to front of furnace beneath charging vestibule.

★ **SAVES FLOOR SPACE** . . . overall dimensions approximately 16-feet long (including quench tank) by 9-feet wide by 13-feet high. Occupies only 144 square feet of floor space.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES



Heating for forging 1" stainless hex-head machine bolt blanks with 10,000 cycle TOCCO Induction Heating Unit. Photo — courtesy The H. M. Harper Co.

with TOCCO* Induction Heating

● Naval Bronze, Silicon Bronze, Copper, Aluminum, Monel and all types of stainless steel are heated for forging at the H. M. Harper Co., Morton Grove, Illinois. Regardless of material TOCCO can be profitably applied to brazing, heat-treating and forging operations in almost any metal-working plant.

PRODUCTION UP — In addition to the very important savings in forging dies, TOCCO has increased production to as much as 265% of output possible with former heating methods. On the 1" type 303 Stainless machine bolt blanks shown here TOCCO upped production from 75 to 200 parts per hour, using 35 K.W., 10,000 cycles.

VERSATILE — The same TOCCO machine is used on stock of ⅜" to 1¼" diameter; heated zones vary from ½" to 4". TOCCO'S automatic timing cycles provide complete uniformity of heating throughout both length and cross section—assuring a uniformly high quality product.

●

Why not have a TOCCO Engineer investigate your plant to determine where TOCCO can cut your costs and streamline your production?

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

NEW FREE BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-8, Cleveland 1, Ohio

Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

Name _____
Position _____
Company _____
Address _____
City _____ Zone ____ State ____

Supersonic Inspection

guards the quality of Bethlehem Tool Steel

Millions of electrical impulses per second probe into billets and bars of Bethlehem Tool Steel, searching for possible voids, piping, or other deviations from high quality. A unique instrument, known as the Supersonic Reflectoscope, makes possible this remarkable examination of a tool steel bar's internal condition by sending high-frequency sound waves through the steel and "bouncing" them back.

Bethlehem applied this inspection method to tool steel and established its reliability over a period of nearly four years. It is especially useful where our past experience has indicated the value of this additional precaution in certain bar sizes.

To users of Bethlehem's fine tool steels, supersonic inspection means a big step forward in the direction of additional quality control. It gives real assurance of soundness, cleanliness, and freedom from flaws in the cross-sections of tool steel bars.

When you need tool steel . . . no matter what the application may be . . . you can count on the ultimate in quality by specifying Bethlehem. The complete range includes: Carbon, Oil- and Air-Hardening, Shock-Resisting, High-Speed and Hot-Work grades.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

Export Distributor:
Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Bethlehem SUPERSONIC TESTED **Tool Steel**

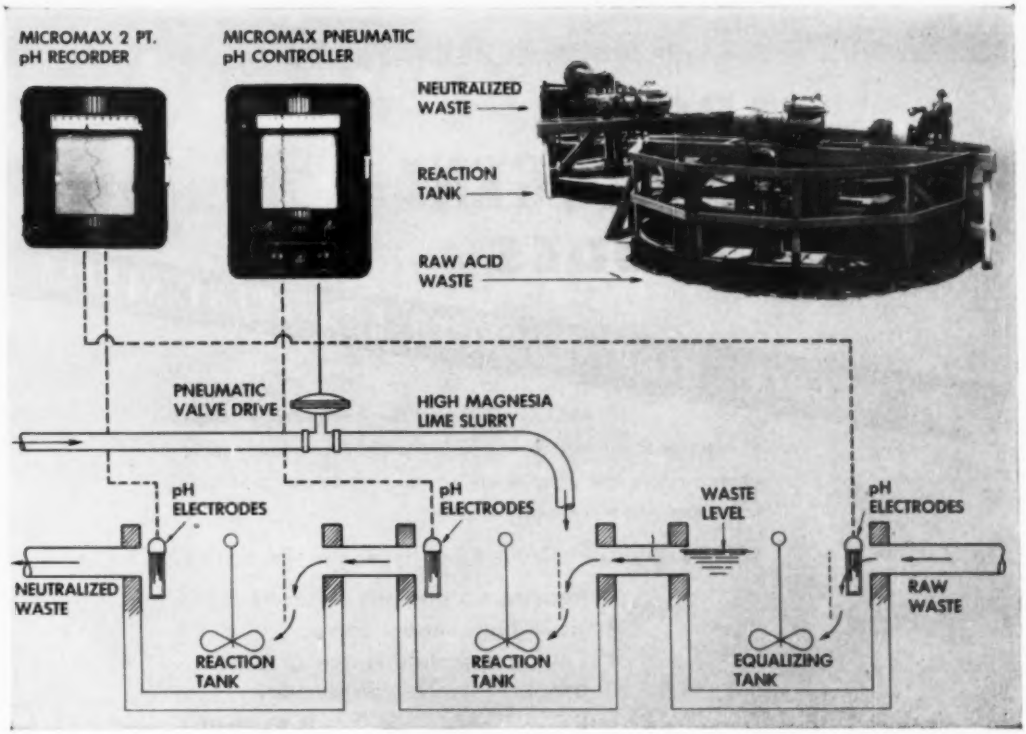


Diagram shows how acid wastes from a typical big plant are neutralized effectively by controlled addition of lime slurry. Micromax instruments automatically regulate lime feed, and record pH of raw and treated wastes.

Want a pH control to fit *your* plant?

One of the country's largest drug and chemical manufacturers faced a waste disposal problem which had some intricate angles. It involved neutralization and disposal. It required better operation of existing equipment. But analysis of the situation, plus correct control, brought the right answer.

First, in cooperation with the plant's engineers, we studied the whole situation. The waste was acid. It varied in quantity. It varied widely in concentration. Waste was to be neutralized by high magnesia lime—relatively slow in rate of reaction. And there were other factors.

After examining these control variables, pH instrumentation recognizing all pertinent facts was arrived at by our proved method of "controllability analysis". This analysis weighed *all* pH control factors—acidity of waste, treating system, reagent. It showed proper arrangement of correct retention capacities. It accurately predetermined the *net control effect*. And the analysis required only a little time.

If, like this firm, you're planning pH control, you can't afford to miss this special service. Write to Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Pa.

Remember . . . write for Bulletin ND44-96-708—

This handy booklet shows the many benefits of automatic pH control in "Effective Neutralization of Industrial Wastes". It explains how our controllability analysis works. It even contains a simple questionnaire so we can help you solve your plant's pH problems *now*. Send for a copy.

LEEDS & NORTHRUP COMPANY, 4927 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

Jrl. Ad ND44-96-708(3)

Metal Progress is published and copyrighted, 1949, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

ARCOS
LOW HYDROGEN
ELECTRODES

FOR WELDING HIGH STRENGTH LOW ALLOY STEELS

ARCOS pioneered the low hydrogen type of electrodes during the war years to produce sound welds when welding low alloy steels such as chrome-molybdenum, vanadium and nickel alloy steels.

ARCOS *quality-controlled* low hydrogen electrodes

- ★ Require no preheat on many jobs.
- ★ Have high impact values.
- ★ Give a complete range of tensile properties with high ductility.

	Yield Strength, psi	Tensile Strength, psi	Elongation in 2"	Reduction in Area
Manganend 1M	70- 85,000	90-100,000	20-30%	40-70%
Manganend 2M	85-105,000	100-125,000	10-20	15-20
Nickend 1	62- 69,000	70- 80,000	25-30	50-60
Nickend 2	65- 75,000	80- 90,000	20-30	45-60

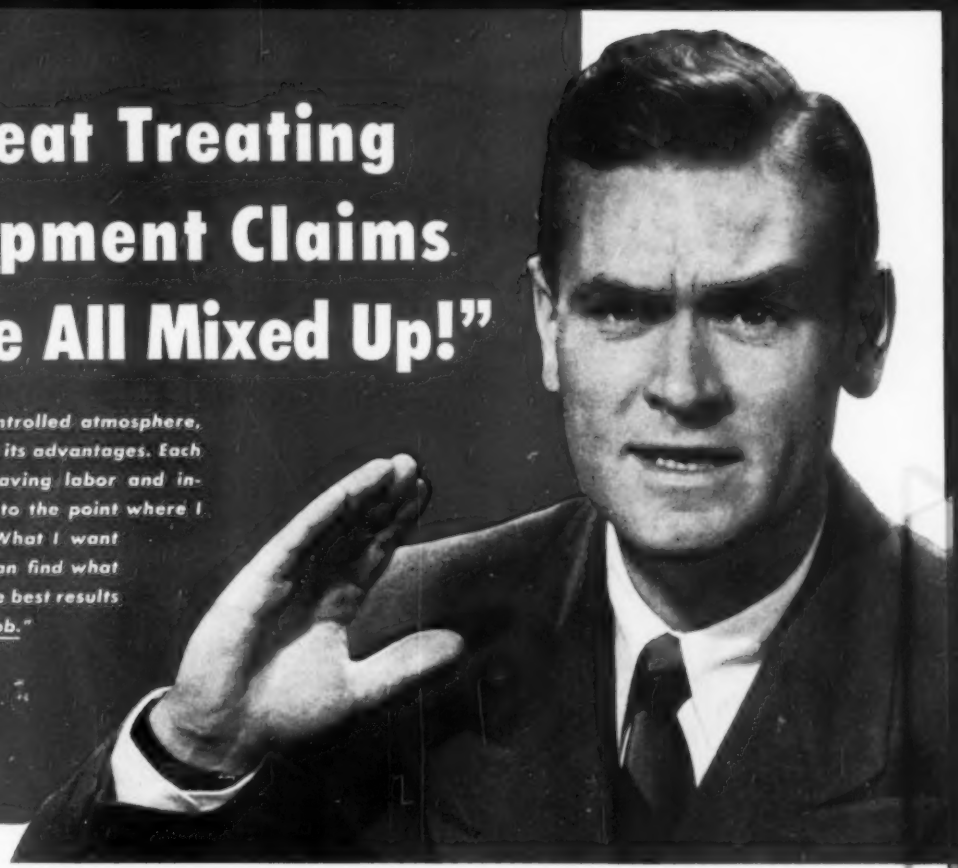
ARCOS Low Hydrogen Electrodes are recommended for welding:

- ★ Low alloy cast steels.
- ★ Low alloy high tensile strength rolled steels.
- ★ High carbon steels.
- ★ High carbon to mild steels.
- ★ Free machining steels.

Send for ARCOS Bulletin 1249 containing more specific information on the use of ARCOS LOW HYDROGEN ELECTRODES.

ELECTRODES • COILED WIRE • BARE ROD

"Heat Treating Equipment Claims Get Me All Mixed Up!"



"Gas, electronic, controlled atmosphere, salt bath! Each has its advantages. Each is advertised as saving labor and increasing efficiency to the point where I get all confused. What I want to know is how I can find what equipment will give best results on my particular job."

Despite the tremendous progress in all types of equipment, it is obvious that the perfect heat treating method has not yet been found—and probably never will. Thus, furnace selection becomes a matter, not so much of reading the ads, as of marshalling actual performance features of competing types, then basing judgment on indisputable facts as they pertain to your particular job.

We make our share of claims for Ajax Electric Salt Bath Furnaces, too. Beyond these, however, and by way of specific proof, we offer the services of the Ajax Metallurgical Laboratory.

The Laboratory service plan is simply this: Let us heat treat a batch of your materials here under shop conditions and in your presence. Let us make it easy for you to see and evaluate the Ajax salt bath method in actual working test before making your heat treating equipment investment!

Hundreds of leading concerns have already taken advantage of this opportunity and a large percentage of them are now among the users of Ajax furnaces.

There is no cost or obligation on your part. It is simply that we prefer to sell equipment on a definite performance basis—and, also that this policy accounts in large part for the tremendous increase in Ajax Electric Salt Bath, Furnaces throughout industry as well as for the high degree of heat treating satisfaction they deliver.

***TIPS AND TRENDS** . . . This Ajax publication issued periodically, helps keep you abreast of salt bath heat treating methods, developments and "know how". Get your name on the list to receive it regularly.*

OVER 3,000 INSTALLATIONS
(more than all other electric salt baths combined) — for

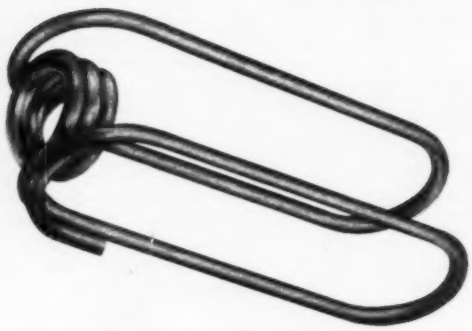
CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING or HARDENING STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
DRAWING (TEMPERING)
SOLUTION HEAT TREATMENT
DESCALING
DESANDING
CLEANING

AJAX HULTGREN **ELECTRIC SALT BATH FURNACES**

AJAX ELECTRIC COMPANY, INC.
910 Frankford Avenue Philadelphia 23, Pa.
THE WORLD'S LARGEST MANUFACTURER OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY
IN CANADA: Canadian General Electric Co., Ltd., Toronto, Ont.
ASSOCIATE COMPANIES: Ajax Metal Co., Ajax Electric Furnace Corp., Ajax Electrothermic Corp., Ajax Engineering Corp.

LOOKING FOR A NEW

Twist?



Wallace Barnes Springs

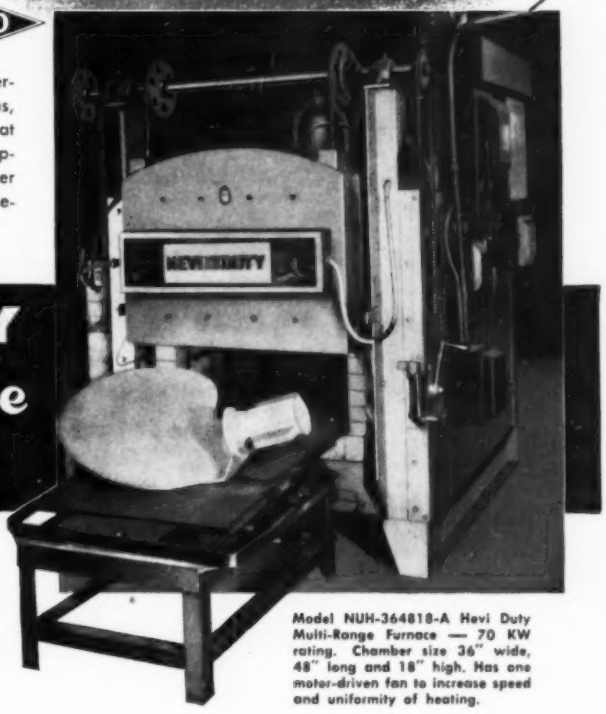
Bristol Connecticut

...Accurate Control...

is a MUST at AMPCO METAL, Milwaukee

Case History at AMPCO

To obtain definite physical properties that meet strict specifications, this large propeller blade is heat treated at a predetermined temperature and held for the proper number of hours to produce desired results.



Model NUH-364818-A Hevi Duty Multi-Range Furnace — 70 KW rating. Chamber size 36" wide, 48" long and 18" high. Has one motor-driven fan to increase speed and uniformity of heating.

HEVI DUTY Multi-Range FURNACES

Ampco alloys are made in various grades and modifications. The modifications depend on heat treating which must be accurately controlled to obtain desired physical properties. One of the great advantages of Hevi Duty Furnaces is their ability to hold uniform temperatures throughout the heat.

Hevi Duty Multi-Range Furnaces are all-purpose furnaces that give you a range of temperatures from 400°F. to 1850°F. with a high degree of uniformity. They are available with single or multiple fans and controls for special programs.

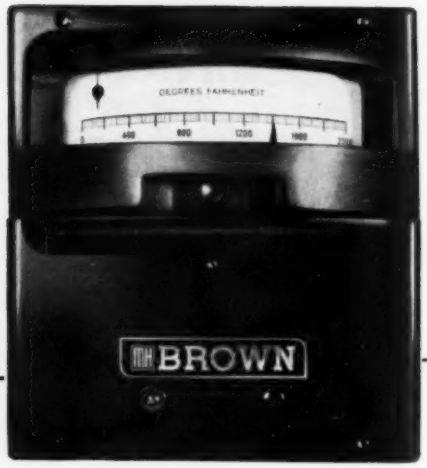
Send for Bulletin HD-341

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES **HEVI DUTY** ELECTRIC EXCLUSIVELY

DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS

MILWAUKEE 1, WISCONSIN



If you're looking for furnace protection ..... don't overlook

The NEW

PROTECT-O-VANE

the modern excess temperature cut-off

HERE'S temperature protection brought up-to-date . . . with every feature that you would include if you designed and built it yourself. Field tests show that it meets your every requirement, and affords a new high in work load protection.

Check these Protect-O-Vane advantages:

- √Provides flashing signal to give adequate warning before shut-down.
- √Reset must be manual and is not effective until temperature drops below safe point.
- √Thermocouple burn-out feature provides additional work-load protection.
- √Case is universal . . . for flush or surface mounting.

Your local Honeywell engineer is ready to give you the facts and figures. Call him in, today . . . or write for a copy of Specification Sheet 113.

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
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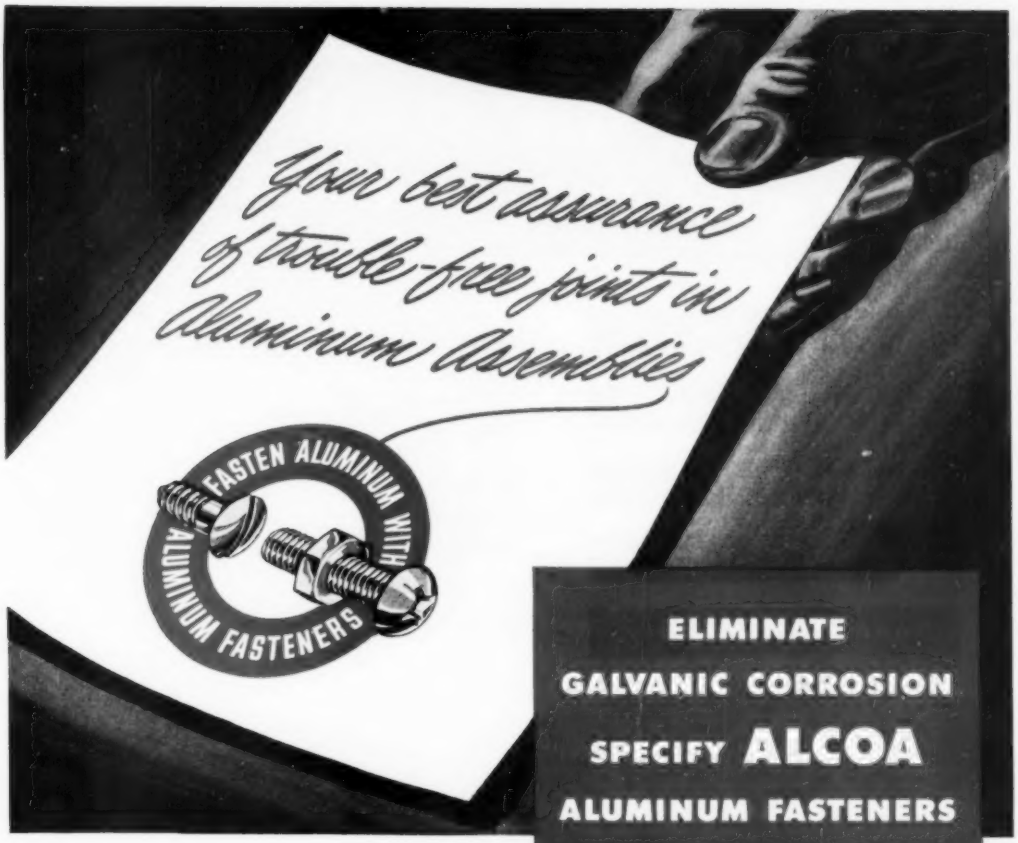
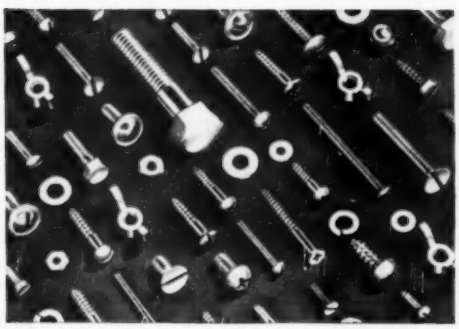
Branch offices in 73 principal cities of the United States, Canada and throughout the world

MINNEAPOLIS Honeywell

Advanced Instrumentation FOR METAL PROCESSING

BROWN INSTRUMENTS





You can prevent the galvanic corrosion that can result when dissimilar metals are used to fasten aluminum assemblies: Fasten aluminum with Alcoa Aluminum Fasteners.

Alcoa Fasteners are available from stock with Phillips heads for fast, slip-free power driving, or slotted heads; in sheet metal, wood and machine screws; all popular sizes, standard threads. Nuts, bolts, washers, lock washers, solid or tubular rivets and cotter pins are also available.

Investigate the low costs and sales advantages of Alcoa Aluminum Fasteners today. Write on your letterhead for free samples, specifying the type and size you'd like. ALUMINUM COMPANY OF AMERICA, 2101L Gulf Building, Pittsburgh 19, Pennsylvania.

ALCOA

ALCOA *Aluminum* FASTENERS

INGOT • SHEET & PLATE • SHAPES, ROLLED & EXTRUDED • WIRE • ROD • BAR • TUBING • PIPE • SAND, DIE & PERMANENT MOLD CASTINGS • FORGINGS • IMPACT EXTRUSIONS
ELECTRICAL CONDUCTORS • SCREW MACHINE PRODUCTS • FABRICATED PRODUCTS • FASTENERS • FOIL • ALUMINUM PIGMENTS • MAGNESIUM PRODUCTS

See what "FM" stainless can give your products

High sales appeal and lasting customer satisfaction are among the many advantages of Armco Stainless Steel bars and wire in your products.

Resistance to heat and corrosion "pay off" with your customers; free-machining properties of the chromium-nickel and the chromium grades help you produce machined parts profitably.

You can machine Armco 18-8 FM, Type 303, and Armco 12FM, Type 416, at speeds ranging between 75% and 85% of those used for Bessemer screw stock.

Chemical and mechanical properties of the two grades differ (see table).

If your product-problem is corrosion or strength, consider the advantages of these solid rustless steels that *never need plating* or *replating*. Then let's talk it over. We're sure you'll find one of the Armco Stainless grades the most satisfactory, most saleable metal for your products.*

Write Armco Steel Corporation, 3539 Curtis Street, Middletown, Ohio. Export: The Armco International Corporation.

*Other Free Machining grades of Armco Stainless Steel include Armco 17FM (Type 430F), Armco 13-C-33FM (Type 420F) and Armco 17-C-100 FM (Type 440F).

ARMCO

ARMCO STEEL CORPORATION

TABLE 1

CHEMICAL ANALYSIS

Type	Carbon (Max.)	Manganese (Max.)	Chromium	Nickel	Molyb. or Zirconium (Max.)	P, S or SE (Min.)
303	0.15	2.00	17.0-19.0	8.0-10.0	0.60	0.07
416	0.15	1.25	12.0-14.0		0.60	0.07

TYPICAL MECHANICAL PROPERTIES

Type	Size and Condition	Ultimate Tensile Strength, psi.	Yield Strength 0.2% Offset psi.	Elonga. in 2", %	Hardness	
					Brin.	Rock.
303	1" Annealed and Cold Drawn	100,000	60,000	40	212	B95
416	1" Tempered and Cold Drawn	100,000	85,000	13	205	B94

TABLE 2

CUTTING RATES

AISI Types Based on These Brinell Ranges	303 150-240	416 180-240
SURFACE FEET PER MINUTE		
Automatic Screw Machine	100-130	120-150
Heavy Duty Spindles	90-120	110-130
Turret Lathe	90-120	100-130
Milling	40-60	50-80
Threading	10-25	10-25
Tapping	10-25	10-25
Drill Press	50-80	60-90
Single Point Turning Carbide Tooling		
Roughing	150-250	150-200
Finishing	200-400	200-400
High Cobalt or Cast Alloy		
Roughing	100-150	100-150
Finishing	150-200	150-200
Tungsten or Moly. High-Speed Alloy		
Roughing	70-90	80-100
Finishing	100-140	100-150

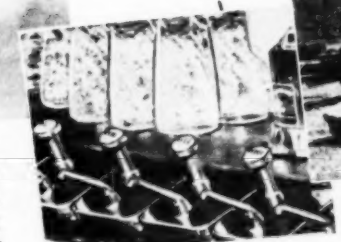
Small Castings that do BIG JOBS

Forward-looking design engineers find that Microcast, for small components, offers many opportunities for product improvement and substantial savings in cost. This is particularly true where resistance to wear or corrosion is desired or where the part is of intricate shape, requiring expensive machining operations under conventional production methods.

With the Microcast Process, the unusual properties of the extremely hard, high-melting-point alloys can be used to full advantage. Small components of intricate shape, as cast, are dimensionally uniform, of sound structure, and to such close tolerances that little or no machining is required.

SPECIALISTS IN POWER BLADING

The "guts" of any turbine-type power development unit is its power blading. The Microcast Process has produced millions of these blades, utilizing the high-melting-point, non-machineable alloys at substantially lower costs than other methods of manufacture.



TIME FOR REFRESHMENT

When you step up to your favorite fountain chances are the syrup for your soda, pumps through a Microcast dispensing part. What's important is that these 18-8 stainless steel Microcastings resulted in considerable savings in die and machining costs over previous production methods.

IT AIN'T HAY

At least the operation is not complete until the modern hay baler goes into action! A Microcast gear on the knotter twine disc assembly eliminates the costly milling and hobbing operations ordinarily required to form teeth.

Microcastings...IN A WIDE VARIETY OF PRODUCTS

AFFORD BETTER PERFORMANCE AT LOWER COST

Write for New Microcasting Booklet

MICROCAST PRECISION CASTINGS PROCESS

MICROCAST

COPYRIGHT 1949, AUSTENAL LABORATORIES, INC.

More complete information on Microcast is contained in a new 16-page booklet published by Austenal Laboratories, Inc., originators of the Microcast Process. The booklet describes many applications for Microcasting and also explains the process itself. Write for your copy today.

The name MICROCAST is a registered trademark of Austenal Laboratories, Inc.

MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 39th Street • New York 16, New York
715 East 69th Place • Chicago 37, Illinois

Silicon Bronze Proves BETTER and CHEAPER!
SHOO PROBLEM!
HOW ALUMINUM SAVES MANPOWER
HANGLES — WITH CARE!
MOO JUICE to MALT JUICE!
For High Strength without Heat Treatment!
Federated METALS

PROOF OF SERVICE!

. . . serves to prove Federated First in the Non-Ferrous Field.

Each one of the ads above highlights a case in which the stamp "SERVICED BY FEDERATED METALS" means that a foundry was helped to cast a better product. And better products mean more customers!

This same service . . . in the person of experienced field and research metallurgists . . . is yours for the asking when you buy from Federated. See Federated first for all non-ferrous metals and alloys.

Federated first in the non-ferrous field. FMD

Federated METALS DIVISION

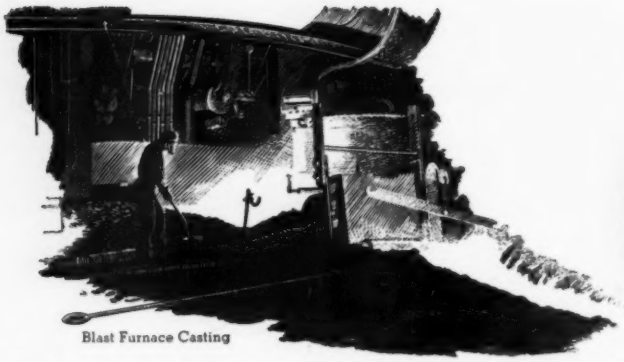
AMERICAN SMELTING AND REFINING COMPANY, 120 BROADWAY, NEW YORK 5, N.Y.

The weight's in the load and not in the truck when frames, body panels, fenders, wheels and other truck structural parts are made of N-A-X HIGH-TENSILE. And while affording weight savings of up to 25% in section, the high physical properties of N-A-X HIGH-TENSILE insure superior strength and increased resistance to fatigue, corrosion, abrasion and denting.

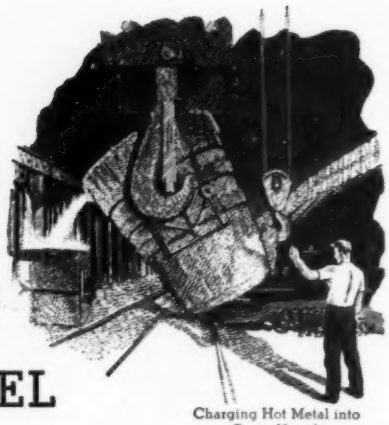
This decrease in deadweight decreases on-the-job expenses, too. Trucks built with N-A-X HIGH-TENSILE consume less gasoline . . . require less maintenance . . . give longer service. And the excellent formability, weldability, and fine surface texture of N-A-X HIGH-TENSILE mean that you build them better, with no added fabricating problems.

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
N·A·X
HIGH-TENSILE STEEL

GREAT LAKES STEEL CORPORATION N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
Unit of National Steel Corporation



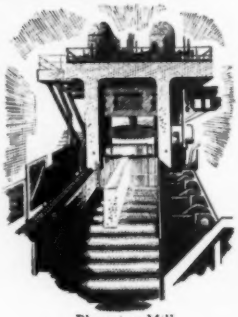
Blast Furnace Casting



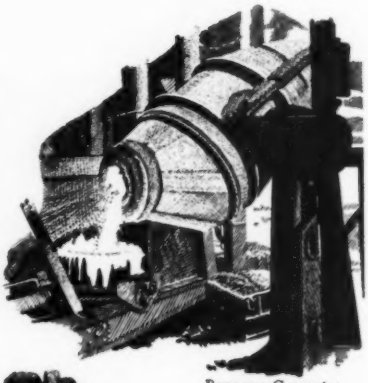
Charging Hot Metal into Open Hearth

AS GOOD AS THE STEEL
from which they are drawn

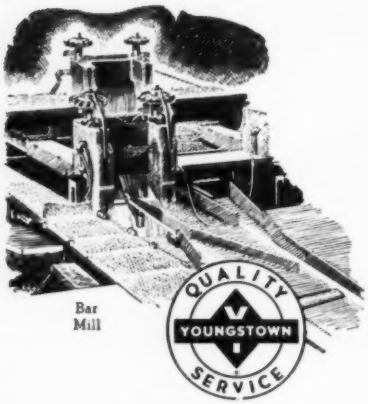
THE experience of nearly 50 years in producing Youngstown Steel in grades and analyses to meet our customers' most exacting requirements is your best insurance of the high quality of Youngstown Cold Finished Bars.



Blooming Mill

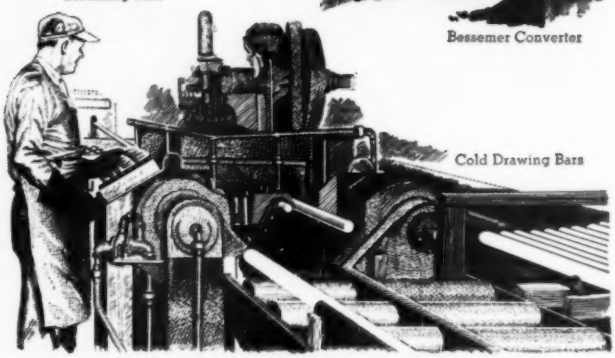


Bessemer Converter



Bar Mill

QUALITY V YOUNGSTOWN SERVICE



Cold Drawing Bars

Youngstown
COLD FINISHED CARBON AND ALLOY STEEL BARS

THE YOUNGSTOWN SHEET AND TUBE COMPANY

Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices Youngstown 1, Ohio

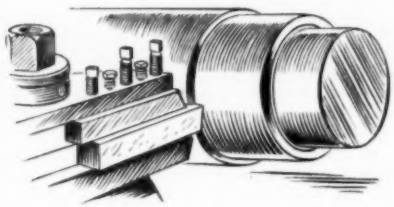
Export Office - 500 Fifth Avenue, New York

COLD FINISHED CARBON AND ALLOY BARS - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - WIRE - PIPE AND TUBULAR PRODUCTS - CONDUIT - RODS - SHEETS - PLATES - BARS - RAILROAD TRACK SPIKES.

how VANADIUM improves—

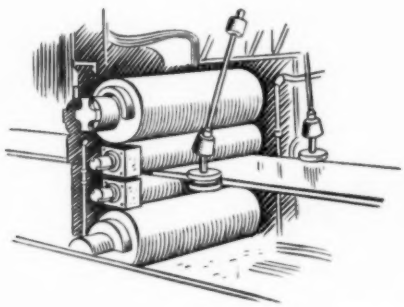
Engineering Steels...

Vanadium steels are tough because of their uniformly fine grain size. They are especially suitable for parts subjected to high dynamic stress. Vanadium-bearing steels also show exceptional resistance to abrasion and fatigue. Parts can be readily cast, rolled, or forged.



Tool Steels...

Nearly all fine tool steels contain vanadium. In the carbon-vanadium grades, this alloy helps control hardenability and improves cutting qualities. Vanadium carbides promote fine grain size and high wear resistance in all tool steels. High-speed steels depend on vanadium for a large measure of their high-temperature hardness.



Cast Iron...

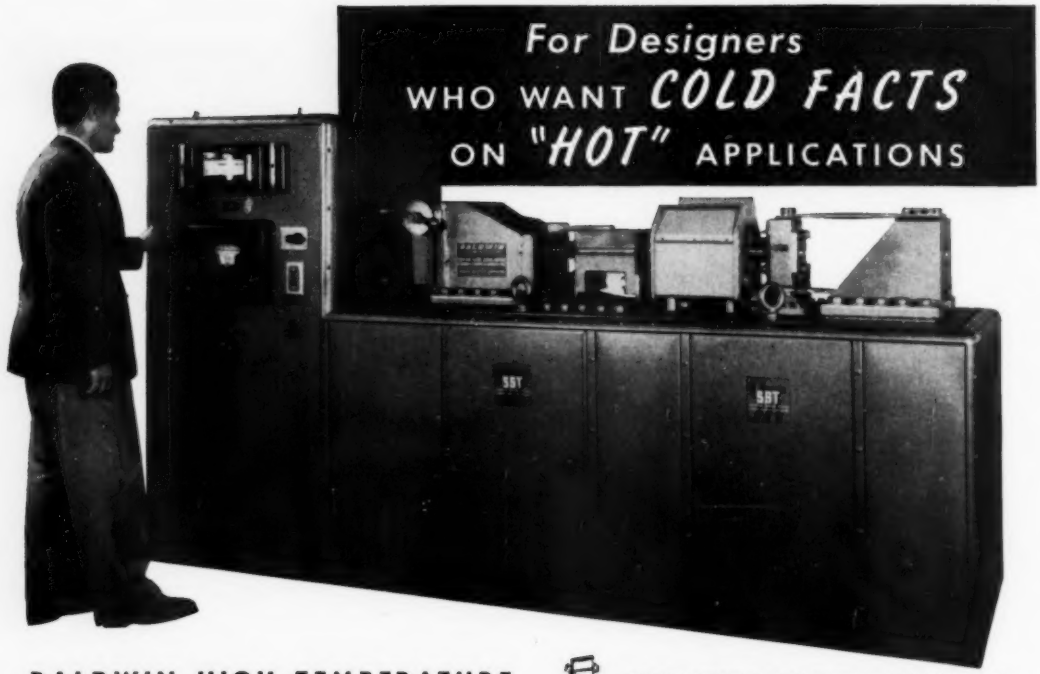
In iron castings, such as those used for rolls in steel reduction mills, vanadium is an essential alloy. When added in amounts of 0.10 to 0.15 per cent, vanadium produces a marked increase in the strength of iron. Vanadium also helps produce castings which are remarkably free from growth and distortion and are suitable for service at moderately high temperatures.

Let our metallurgists show you how you can produce stronger, more uniform steel or iron by using vanadium. They will also gladly give you on-the-job technical assistance in the use of any other ELECTROMET ferro-alloy or alloying metal.

Write to the nearest ELECTROMET office.

ELECTRO METALLURGICAL DIVISION
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
OFFICES: Birmingham • Chicago • Cleveland • Detroit
New York • Pittsburgh • San Francisco
In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

Electromet
TRADE-MARK
Ferro-Alloys and Metals

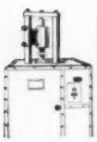


BALDWIN HIGH TEMPERATURE TESTING EQUIPMENT . . . There's a "fourth dimension" in testing today, bounding a new field where the properties associated only with length, breadth and thickness are inadequate to forecast performance.

This new dimension is *temperature*. The progress made to date in high-pressure steam turbines, in gas turbines, in jet engines, and in oil refinery equipment, has rested on the designers' knowledge of the effect of elevated temperatures on the properties of metals. Further progress will depend on the speed with which the horizons of this knowledge are expanded.

To aid explorers in this field, Baldwin has developed these interesting new items of high temperature testing equipment. Furnaces which are supplied as standard equipment are suitable for obtaining temperatures up to 1800° F. Special furnaces are available which will produce temperatures up to 2200° F.

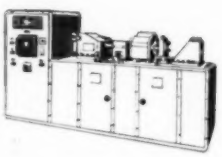
BALDWIN LEVER TYPE CREEP MACHINE. Maximum capacity 12,000 lbs. Loading accuracy within 1% of load, and accuracy of strain measurement is within .00005-inch. Over 150 of these machines are now in use in leading laboratories.



BALDWIN SONNTAG SF-4 FATIGUE MACHINE. The first "constant force" fatigue machine permitting application of furnace and control equipment for direct stress fatigue testing at elevated temperatures. Static pre-load 0 to 8,000 lbs.; dynamic load capacity ±5,000 lbs. Maximum capacity, one direction, 13,000 lbs.

BALDWIN SCREW TYPE CREEP RUPTURE MACHINE. Motor driven, capacity 20,000 lbs. Automatically maintains loads while temperature is held constant. Flat chart recorder plots elongation vs. time.

BALDWIN CONSTANT STRAIN RATE CREEP TESTING MACHINE. For determination of effect of various strain rates on the breaking points of metals, at controlled high temperatures. Head velocity can be varied from 0.6 inches to .000001-inches per second.



BALDWIN SONNTAG SF-5 FATIGUE TESTING MACHINE FOR TURBINE BLADES. Maintains a predetermined fixed load up to 8,000 lbs. while applying alternating flexure loads up to ±1400 lbs. at controlled high temperatures. Simulates service conditions.

HELPFUL TECHNICAL LITERATURE AVAILABLE. Technical bulletins, giving full details on the various equipment described above are available on request. Please indicate the machine in which you are interested, or the type of testing that you plan on doing.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Boston, New York, Philadelphia, Houston, St. Louis, Chicago, Cleveland, Pittsburgh, San Francisco, Seattle, Washington. In Canada: Peacock Brothers, Ltd., Montreal, Quebec.

testing headquarters → **BALDWIN**

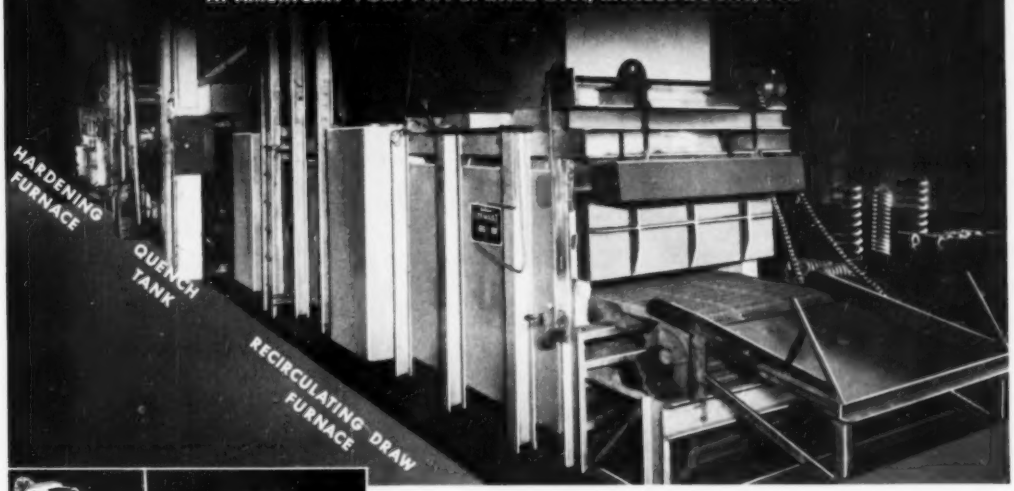
No. 97 of a Series of Typical Installations

Sunbeam STEWART

THE BEST INDUSTRIAL FURNACES MADE

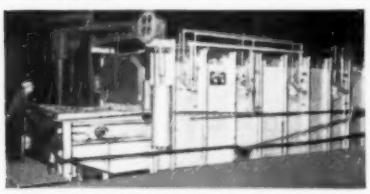
HEAT TREATING RAILWAY AND INDUSTRIAL SPRINGS

At AMERICAN-FORT PITT SPRING DIV., McKEES ROCKS, PA.



Overall view of the integrated Sunbeam Stewart Harden, Quench and Draw heat treating line (approximately 100 ft. long) for helical springs. This installation is capable of handling 3,500 lbs. per hour.

An exclusive double belt conveys springs through the quenching oil. This design eliminates impact, permits an even quench along the longitudinal axis of the spring.



Overall dimensions of the Hardening Furnace are 11½' by 30½', with a usable hearth space of 54" by 25'.

This is Number 97 in a series of typical installations showing how Sunbeam Stewart Furnaces are helping manufacturers reduce costs and keep themselves competitive. These installations also demonstrate the wide variety of specific requirements in the metal-working industry Sunbeam Stewart Furnaces are designed to meet.

Springs manufactured by American-Fort Pitt Spring Division of the H. K. Porter Co., Inc., are such as those used in the agricultural implement and railroad fields, with a monthly production of about 700 to 800 tons.

To eliminate distortion of springs due to shock and impact, a double belt conveyor automatically delivers springs from the Hardening Furnace through the quench tank to the Draw Furnace. The upper belt runs slack so that its weight holds the spring firmly until quenched.

It will pay to consult Sunbeam Stewart on your heat treating problems. In addition to continuous conveyor units, Sunbeam Stewart builds a full line of standard furnaces and galvanizing equipment.

SUNBEAM STEWART INDUSTRIAL FURNACE DIVISION of SUNBEAM CORPORATION

(Formerly CHICAGO FLEXIBLE SHAFT CO.)

Main Office: Dept. 108, 4433 Ogden Ave., Chicago 23 — *New York Office:* 322 W. 48th St. New York 19 — *Detroit Office:* 3049 E. Grand Blvd., Detroit

Canada Factory: 321 Weston Rd., So., Toronto 9

A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM STEWART furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM STEWART engineer will be glad to call and discuss your heat treating problems with you.

Sometimes it costs less to use Steel that costs more!

Here, U·S·S COR-TEN used cuts weight 18%

*** The bigger the tank the bigger the saving**

In the 42" x 10' Stonesteel tanks under construction above, the use of COR-TEN reduces weight 553 lb., saves $5.00 on material cost. When these lighter COR-TEN tanks were shipped to a housing development in Norfolk, Va., freight charges were $9.84 less, bringing the total savings per tank to $14.84.

USS

in place of carbon steel

cuts material cost 10.8%

cuts shipping cost 16%

During the past 12 years, U·S·S Cor-Ten—the pioneer high strength steel—has earned a world-wide reputation for reducing costs by reducing weight in freight cars, buses, trucks and other mobile equipment. That's exactly what Cor-Ten was developed for, so we were not surprised.

But here is the story of a money-saving application, far outside the transportation field, that aptly illustrates how stationary equipment of many kinds can be built advantageously of U·S·S Cor-Ten in place of carbon steel—not only to improve the product but to reduce its cost.

SEVERAL years ago the Cemline Corporation of Cheswick, Pa., developed a hot water storage tank designed to prolong life even in those areas where water supplies are unusually corrosive. A special hydraulic cement lining that prevents corrosion by eliminating any corrosive water-to-metal contact did the trick. But in solving the corrosion problem the cement lining created another. Its substantial weight when added to the weight of the heavy carbon steel shell resulted in a unit that was unwieldy to handle and difficult and costly to install.

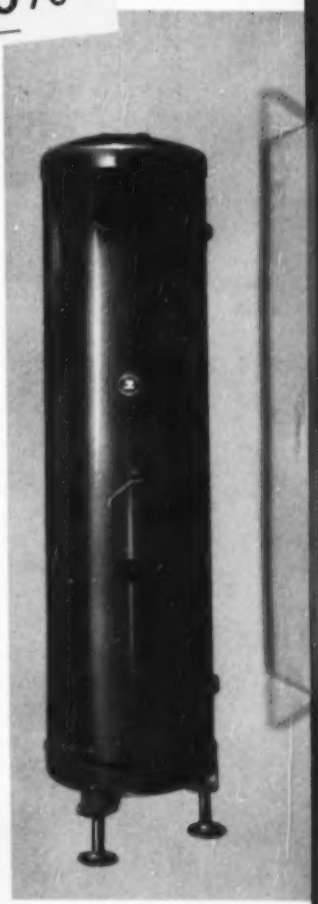
A lighter tank was definitely called for. This need was emphasized with every increase in freight rates, and as more and more tanks were shipped to distant markets. The question was, how to reduce weight and still meet high strength requirements. Cemline engineers found the answer in U·S·S Cor-Ten.

Due to the protective lining, interior corrosion could be disregarded, so they were able to take full advantage of U·S·S Cor-Ten's high yield point (50,000 psi.) and to use it in gages 40% lighter than the carbon steel gages previously required. This 40% reduction in cylinder weight reduced the total tank weight 18%.

These weight savings resulted in cost savings all along the line. Cost of the steel per cylinder was 10.8% less (because the weight saved more than offsets Cor-Ten's slightly higher cost). The lighter tanks were handled with less trouble and less expense. And, freight charges on every shipment—on steel from the mill, on the tanks to the customer—were reduced almost 16%.

To show what this means in actual dollars and cents savings, take the case of the 45-gallon Stonesteel tank (shown at right) produced by the thousands for residential use. Replacing the carbon steel shell, .138" thick, with U·S·S Cor-Ten .0828" thick, reduced weight 42 lb., cut steel cost 35 cents. When these tanks were shipped to Richmond, Va., freight charges were 72 cents less for the lighter tanks, making a total saving per tank of $1.07.*

"U·S·S Cor-Ten," says the President of Cemline Corporation, "does more than reduce our costs. Because of its stiffness it forms more smoothly on our bending rolls, and fluting difficulties formerly experienced have disappeared. In welding, too, Cor-Ten behaves better than straight carbon steel. It does not seem to burn away so readily under the arc and thus makes welding easier and faster. We know our customers have less trouble and less expense handling these lighter Cor-Ten tanks. And because Cor-Ten has from 4 to 6 times greater atmospheric corrosion resistance we have every reason to believe that Stonesteel tanks made of U·S·S Cor-Ten are much less likely to rust when exposed to external condensation, when leaky fittings drip or when the enameled surface is damaged in shipping or installation. That's why, for all our tanks, except where codes require flange steel construction, we've standardized on U·S·S Cor-Ten."



AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
CARNEGIE-ILLINOIS STEEL CORPORATION, PITTSBURGH & CHICAGO
COLUMBIA STEEL COMPANY, SAN FRANCISCO · NATIONAL TUBE COMPANY, PITTSBURGH
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM
UNITED STATES STEEL SUPPLY COMPANY, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

U·S·S HIGH STRENGTH STEELS

U·S·S COR-TEN · U·S·S MAN-TEN · U·S·S MANGANESE-NICKEL-COPPER

United States Steel Corporation Subsidiaries
Room 2088 Carnegie Building, Pittsburgh 30, Pa.

☐ Please send me a copy of booklet showing how U·S·S Cor-Ten saves money in building Stonesteel tanks.

☐ Please have a High Strength Steel representative call on me.

Name.....

Position.....

Company.....

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City.....Zone.....State.....

UNITED STATES STEEL

Ahead in packaging, too!

TAG A.S.T.M. and Standard Grade Thermometers

To remove thermometers, simply raise end of box platform.

Thermometers readily slide in or out of spacing retainers.

TAG—oldest name in the business, with its new WESTON affiliation and new, modern plant, now reasserts its leadership in the field. Makers of the highest grade thermometers since 1769, TAG is *first* to develop this unique, improved thermometer packaging*. The compact, handy design means new convenience, less cumbersome handling for you. Result: reduced breakage, faster inspection, easier testing and uniform stocking.

Complete specifications on each box label. Available in lots of three or six to a box. Comprehensive stocks. Order from your laboratory supply dealer, or direct from us. Catalog 1100 lists and describes the complete line of TAG Thermometers and Hydrometers and contains useful Fahrenheit-Centigrade conversion tables. Just write for it.

*Patent Pending

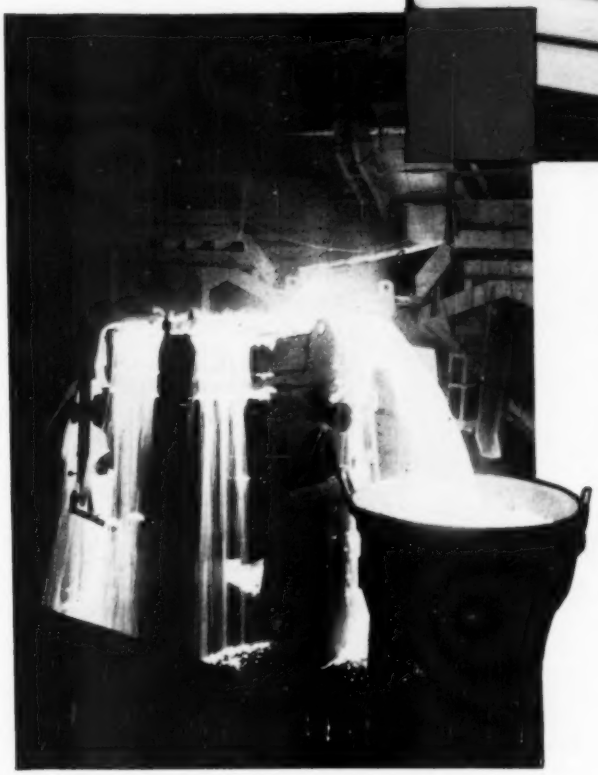
C. J. Tagliabue Corporation (N. J.)

Subsidiary of WESTON ELECTRICAL INSTRUMENT CORPORATION

591 Frelinghuysen Avenue, Newark 5, N. J. Representatives in all Principal Cities

TAG

OUR "WASHBOWL" WEIGHS 200 TONS*



The little girl gets a good bath in a washbowl. At Wisconsin Steel we use a somewhat larger "washbowl."

When producing Sulfite-Treated Steel, we give a ladle full of molten steel a "bath" by "washing out" abrasive inclusions. The result—*a more machinable finished product with an absolute minimum effect on physical properties.*

To discover how Wisconsin Sulfite-Treated Steels can benefit you, contact our sales and technical representatives.

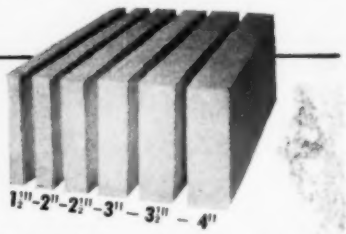
**Weight of ladle full of molten steel*

WISCONSIN STEEL COMPANY, Affiliate of INTERNATIONAL HARVESTER COMPANY
180 North Michigan Avenue • Chicago 1, Illinois

WISCONSIN STEEL

Why the lowest cost open hearth producers use SUPEREX for regenerator insulation

The large size of the Superex blocks saves construction costs



Superex blocks are furnished in various standard sizes and thicknesses

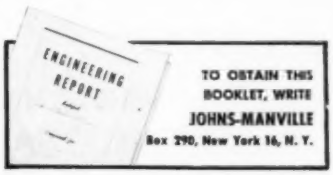
● "Insulate with Superex and you make substantial fuel savings and obtain higher operating temperatures," that's what cost-conscious operators find.

Superex provides these savings year after year. Made of calcined diatomaceous silica and asbestos, it presents a formidable heat barrier. It maintains its high insulating efficiency indefinitely on temperatures to 1900° F. . . . does not disintegrate . . . retains its high physical strength . . . resists the stresses of open hearth and other mill operations.

Higher operating temperatures with Superex result from its ability to reduce air infiltration. This advantage is traced to its unique structure and low permeability.

Superex is light in weight, easily cut and applied . . . comes in convenient standard sizes or may be ordered in irregular shapes.

To help you gain the greatest savings from Superex, Johns-Manville has prepared an engineering report, "Open Hearth Regenerators—a comparison of various insulation specifications." This report indicates the economic thickness of Superex to use as related to the costs of various types of fuels. To obtain this booklet, write Johns-Manville, Box 290, New York 16, N. Y.



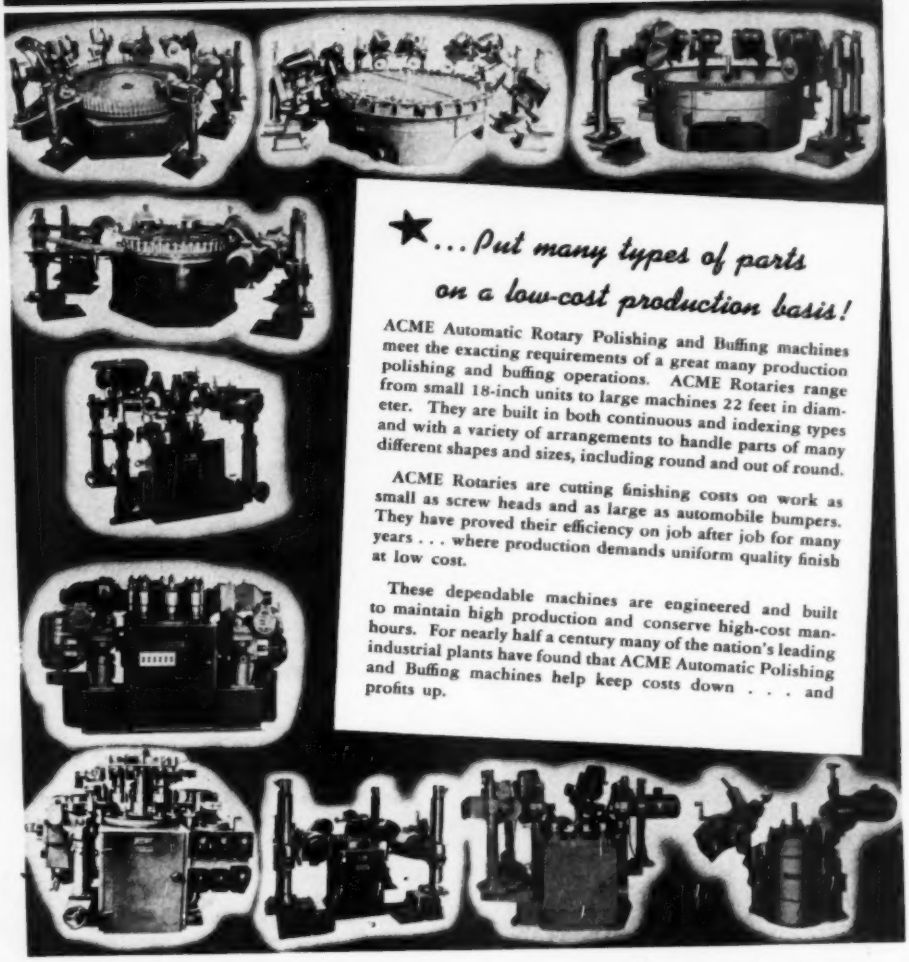
JOHNS-MANVILLE *First in* INSULATIONS

FAHRITE
HEAT AND CORROSION Alloys
STRENGTH
...AT HIGH TEMPERATURES
The Fahrite heat-resistant castings shown are trays, tray baskets, furnace hearths, fixtures, nozzles, shaft and grid. Fahrite is also used for retorts, chain, carburizing boxes, fixtures, centrifugally-cast tube. These, and many others, hold up longer on the job for which they are designed.
At temperatures where ordinary steel would disintegrate, Fahrite castings have the strength needed. There are grades to suit many conditions. Let us recommend the analysis for your specific needs.
Ohio Steel ranks high in the three essentials . . . design . . . metallurgy . . . ability to make good castings.
THE OHIO STEEL FOUNDRY CO.
SPRINGFIELD, OHIO
Plants at Lima and Springfield, Ohio

ROTARY AUTOMATICS • SEMI-AUTOMATICS • STRAIGHT LINE AUTOMATICS

• FOR HIGH PRODUCTION POLISHING AND BUFFING •

ACME ROTARIES



★ ... Put many types of parts on a low-cost production basis!

ACME Automatic Rotary Polishing and Buffing machines meet the exacting requirements of a great many production polishing and buffing operations. ACME Rotaries range from small 18-inch units to large machines 22 feet in diameter. They are built in both continuous and indexing types and with a variety of arrangements to handle parts of many different shapes and sizes, including round and out of round.

ACME Rotaries are cutting finishing costs on work as small as screw heads and as large as automobile bumpers. They have proved their efficiency on job after job for many years . . . where production demands uniform quality finish at low cost.

These dependable machines are engineered and built to maintain high production and conserve high-cost man-hours. For nearly half a century many of the nation's leading industrial plants have found that ACME Automatic Polishing and Buffing machines help keep costs down . . . and profits up.

★ *Save high-cost Man-Hours — with low-cost* ACME *Machine Hours!*

SPECIAL MACHINERY AMC AUTOMATIC BUFFING MACHINES

ACME *Manufacturing Co.*

1645 HOWARD ST. DETROIT 16, MICH.

Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR OVER 30 YEARS

The Case of the Careful Consumers

In these days of increasing production costs, consumers whoever they may be, are exercising the utmost judgment in the selection of the products they specify and buy.

In the case of fabricating with arc welding, the welding electrode costs are usually a relatively small item in the fabrication costs of the product as a whole. Nevertheless, the success or failure of welds in service mean success or failure of the product in service. That is why it is important that the electrodes you buy and use give you the properties you require consistently . . . day-in and day-out.

When you specify McKay Electrodes you can be sure that *every* electrode you get will have consistent chemical and metallurgical properties, outstanding operating characteristics and uniformly reliable performance at economical costs.

* * * * *

Your inquiries and request for samples are invited on McKay Mild-Steel, Alloy-Steel, Stainless-Steel and Special-Purpose Electrodes. Immediate delivery on all grades.

If You Have Arc-Welding Problems of Any Kind

Consult

THE McKAY TECHNICAL STAFF

The men in our Technical Service Division will gladly work with you and recommend the McKay Electrodes you need to accomplish your welding jobs more efficiently, more economically and at less cost. Write today.

McKAY STAINLESS STEEL · MILD STEEL · ALLOY STEEL · WELDING ELECTRODES

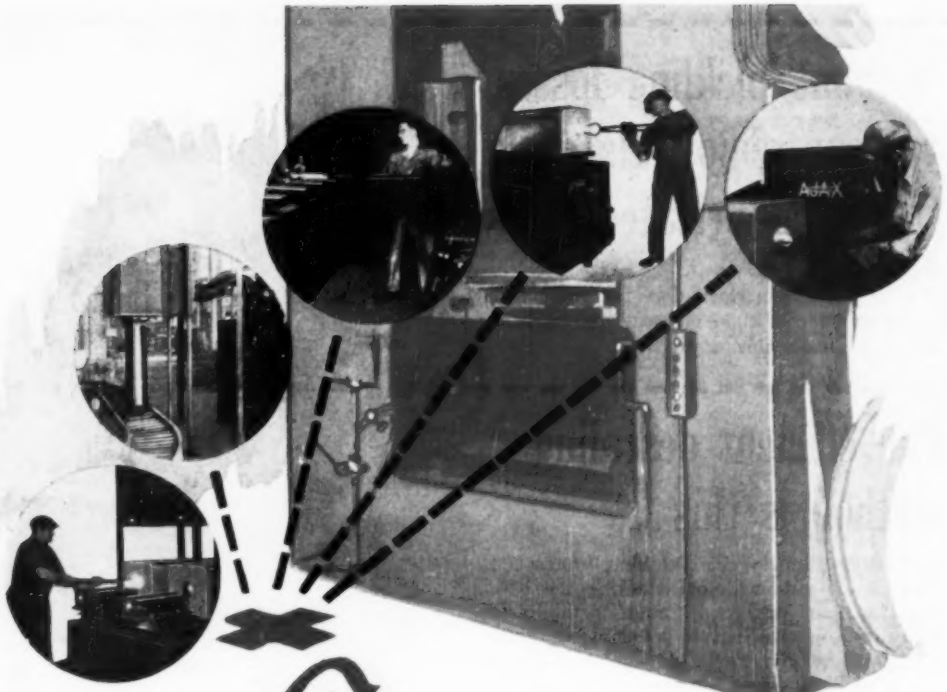
Researched, Developed and Manufactured to Fill Industry's Requirements for Dependable Electrodes

Facilities you can use *Profitably* *in Buying* Medium *and* Small Castings

NE is the well known and long established symbol for quality carbon and alloy steel castings and gears used by industry. Diversified facilities at National Erie Corporation also provide a wide range of medium and small steel castings produced on squeezer and roll-over moulding machines . . . Our Rotoblast equipment illustrated here facilitates economical, speedy cleaning of the wide diversity of small and medium cast parts which we produce for a multitude of light industrial machines. National Erie engineers, metallurgists and craftsmen control every operation from raw materials to finished product within our own plant. We can serve you as we are serving hundreds of others with these complete and diversified facilities. Bulletin No. 7 fully describes our capabilities. Write for it.

NATIONAL ERIE CORPORATION

ERIE, PENNSYLVANIA • U. S. A.



SCALE-FREE *Forging Heat* RIGHT AT YOUR ELBOW

Put Ajax-Northrup forging heaters right beside *your* forging machines and you'll find the same lower overall costs reported by other users of this clean, fast heat! Heats in seconds—no time for scale to form. You can often start with smaller blanks, save tons of steel. 20% saved in one Michigan forge shop!

Die life is longer—scale wear is eliminated, and automatic timing prevents overheated dies. You get greater accuracy, too. In one case, a part weighing 2½ lbs. is held within 2 oz. tolerance on a *forging press.*

Power costs are OK, too—in line with other fuels. Ajax-Northrup can supply efficient forging heaters for practically any heating job.

Think of the savings in steel, time, rejects, and better quality that are possible in your plant with Ajax-Northrup forging heat, then tell us your problem, or write for Bulletin 13.

AJAX ELECTROTHERMIC CORPORATION • Ajax Park • TRENTON 5, N. J.

SINCE 1916

126

AJAX NORTHRUP
HEATING & MELTING

Associate Companies
THE AJAX METAL COMPANY • AJAX ELECTRIC FURNACE CORPORATION
AJAX ELECTRIC COMPANY, INC. • AJAX ENGINEERING CORPORATION

Without pickling losses, you can remove the scale from prefabricated parts

Welded, forged, or cast . . . of any metal or alloy or bimetallic which does not react with molten caustic and whose physical characteristics are not adversely affected at 700°F.

The efficient descaling method is this . . .

Du Pont Sodium Hydride Descaling Process . . . removes all scale without attacking the base metal, without pitting . . . brings metal losses 'way down, reaches hard-to-get-at places, gives a uniform result. Parts retain dimensional accuracy. This speedy cleaning method conditions surfaces for application of hot-dip galvanizing, plating, and other protective finishes.

Get the full story from this booklet

It clearly shows you all the advantages of this process, what it is, how it works and where it is used. Many photographs, diagrams, and important technical data are included. To get the complete story, just clip the coupon, send it to E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

DU PONT

Sodium hydride process for nonelectrolytic descaling

DU PONT

REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.)
Electrochemicals Department
Wilmington 98, Delaware

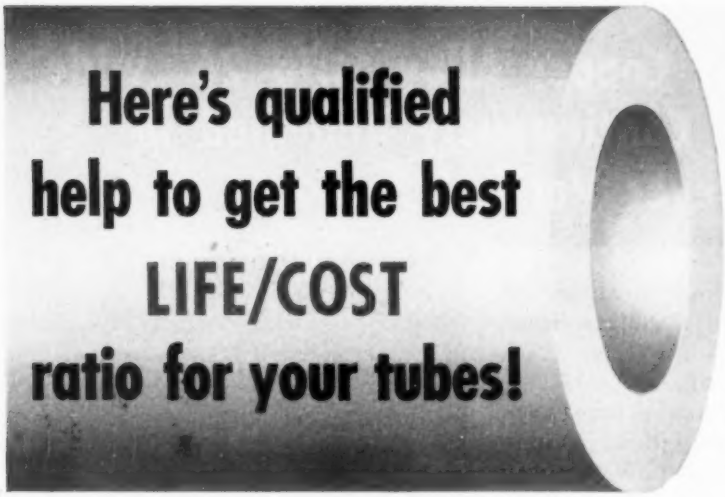
Please send my copy of "Du Pont Sodium Hydride Descaling Process."

Name_____ Position_____

Firm_____

Address_____

Here's qualified help to get the best LIFE/COST ratio for your tubes!



TO be sure of getting the best life/cost ratio from your tubes, you need more than just any steel that answers your particular problems of heat, pressure, corrosion or oxidation. You want the *one specific steel* that gives you all this at the lowest possible cost in terms of service per dollar invested!

That's why it will pay you to call in qualified assistance to help you make your selections.

Metallurgists of The Timken Roller Bearing Company are recognized authorities on high temperature tubing applications. They are backed by 19 years of experience and research. From a wide selection of Timken® fine alloy steels they will select the correct tubing to give you the most efficient and economical performance for your specific job.

And when the correct analysis has been selected, you can be sure of this: Because of rigid quality control by Timken at every step in production, you'll get the same uniform characteristics and the same high quality in every shipment you order.

The Timken Technical Staff will be glad to study your high temperature tube problems at any time, without obligation. Write for your copy of our booklet, "Facilities and Products". The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

TIMKEN 18-8 STEEL TUBES Shows the best combination of creep strength, oil corrosion and oxidation resistance up to 1500°F.

TIMKEN SICROMO 9M STEEL TUBES This steel possesses the maximum corrosion resistance of any of the steels below the stainless group.

TIMKEN SICROMO 7 STEEL TUBES For applications requiring better corrosion resistance than can be obtained with 5% Chromium type steels.

TIMKEN SICROMO 5 S STEEL TUBES For oxidation resistance to 1500°F. Good creep strength and corrosion resistance to 1300°F.

TIMKEN 4-6% CR MO STEEL TUBES For service up to 1200°F. Superior corrosion resistance. Less oxidation resistance than Sicromo 3.

TIMKEN SICROMO 3 STEEL TUBES For service up to 1200°F. Have excellent oxidation resistance and good corrosion resistance.

TIMKEN 2¼% CR-1.0% MO STEEL TUBES For service up to 1150°F. Has greater resistance to creep than 2% Cr. ½% Mo. Steel.

TIMKEN SICROMO 2 STEEL TUBES For service up to 1200°F., where better scale resistance is required than can be obtained with 2% Cr. ½% Mo. Steel.

TIMKEN 2% CR-½% MO STEEL TUBES For service up to 1150°F. Intermediate corrosion resistance plus good creep strength, fair oxidation resistance.

TIMKEN DM STEEL TUBES For service up to 1150°F. This steel offers outstanding creep strength.

TIMKEN CARBON-MO STEEL TUBES For temperature up to 1000°F. Improved creep strength makes it safer than carbon steel.

TIMKEN CARBON STEEL TUBES Generally for service not exceeding 900°F., where corrosion and oxidation resistance are not important.

50th birthday of the company whose products you know by the trade-mark: TIMKEN

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

6000 #/hr. of Copper Alloy Strip 26" wide x .025" Continuously Annealed in Drever Vertical Furnace

Furnace annealing capacity of copper alloy strip ranges from 3100 lb/hr of .0035" to 6500 lb/hr of .050" strip.

The complete line includes pay-off mechanism, strip joiner, continuous degreaser, 360 K.W. vertical annealing furnace with charging and discharging loopers, continuous flash pickling equipment (both acid and bichromate tanks), recoiler mechanism and controlled atmosphere generator.

Continuous annealing of both ferrous and non-ferrous strip offers production economies and a consistently uniform anneal which merit investigation.

DREVER CO.

790 E. Venango Street, Phila. 34, Pa.

New York & New England—Gerald B. Duff, 68 Clinton Ave., Newark 5, N. J.
W. Penna., W. N. Y. and Ohio—H. C. Bostwick, 3277 Kenmore Rd., Cleveland 22, Ohio
Iowa, Minn. & Wis.—Walter G. Barstow, 1302 Fifth Ave. South, Minn. 4, Minn.

WHEN THERE'S HARD WORK AHEAD FOR STEEL PARTS
...use *Republic* Cold Drawn Alloy Steel Bars

When steel parts must carry heavy loads—or withstand severe shock and strain—or resist abrasion resulting from high speed or continuous use—you probably can keep equipment in use longer and *cut maintenance and replacement costs* by using Republic Cold Drawn Alloy Steel Bars.

Republic Alloy Steels are exceptionally high in strength and toughness. They respond uniformly to hardening treatment. In cold drawn bar form, they provide the close tolerance, accuracy of section, fine surface finish and UNIFORM MACHINABILITY characteristic of Union Cold Drawn Products. Thus, they further add to economy by helping to cut parts production costs.

Republic Cold Drawn Alloy Steel Bars are available in all popular analyses, in standard shapes and sizes, furnace treated as you require—annealed, normalized, heat treated, spheroidized, stress relieved or carbon corrected.

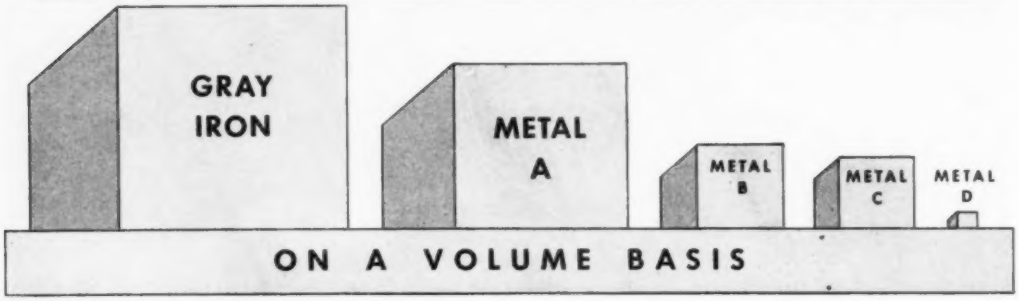
Republic metallurgists are ready *now* to help you get the results you need. Write for further information.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, New York

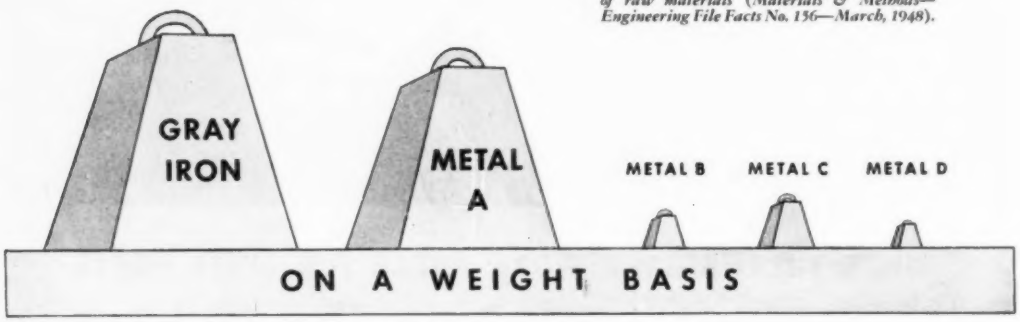
Republic COLD DRAWN
REPUBLIC STEEL
ALLOY STEEL BARS

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

How much metal can you buy for $1



Comparisons in these charts based on the costs of raw materials (Materials & Methods—Engineering File Facts No. 156—March, 1948).



Whether by Volume or by Weight
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For stability and rigidity, there are no substitutes for volume and weight.

So if you need stability and strength in your products, Gray Iron offers you the greatest ultimate economy.

Add to this Gray Iron's other characteristics . . . *castability, rigidity, low notch sensitivity, wear resistance, heat resistance, corrosion resistance, machinability, vibration absorption, durability, wide strength range* . . . and you have an unmatched combination of advantages.

Write Department "E" for free booklet, "GRAY IRON—Its Mechanical and Engineering Characteristics, and Details for Designing Cast Components".

Make It Better with Gray Iron

Second Largest Industry in the Metal-Working Field

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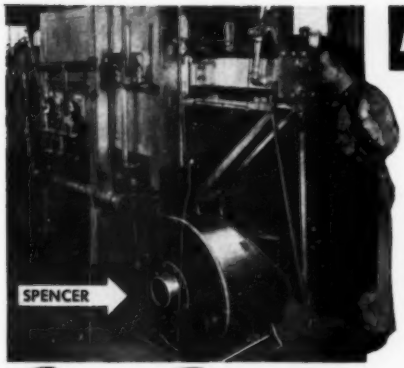
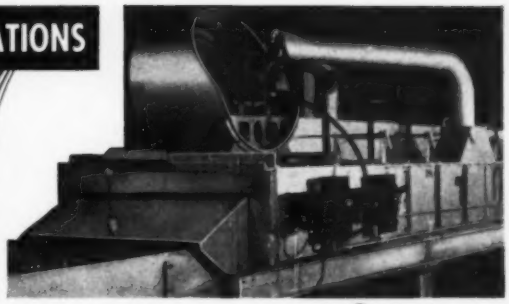
APPLICATIONS

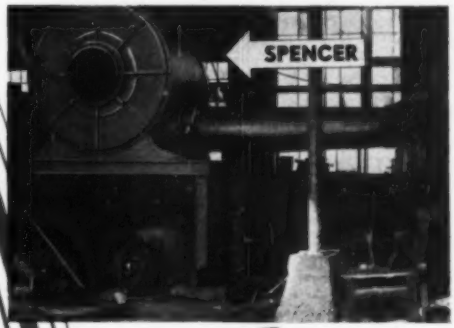


Heat Treating
BULLETIN No. 126

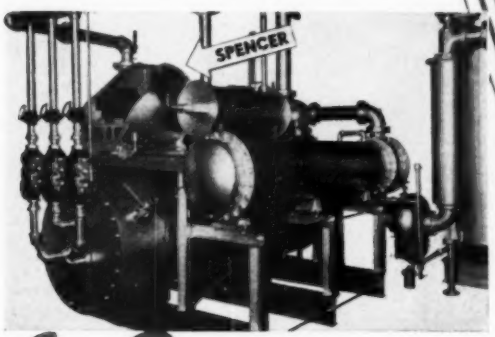


Cooling
BULLETIN No. 127

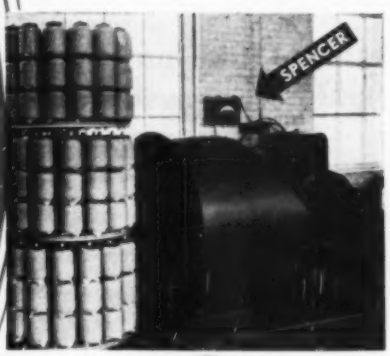
● Ask for the Spencer Turbo Data Book and any of the bulletins mentioned.



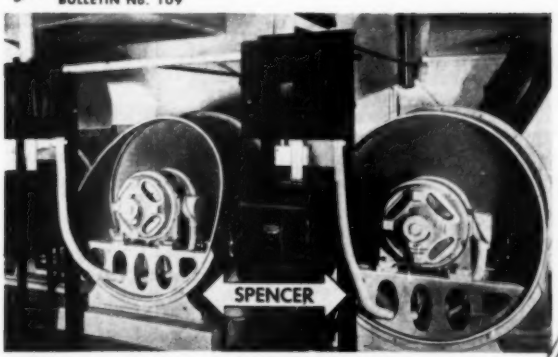
Foundry
BULLETIN No. 112



Gas Booster
BULLETIN No. 109



Blowing
BULLETIN No. 127



Pneumatic Tube
BULLETIN No. 104

THE SPENCER TURBINE COMPANY
HARTFORD 6, CONN.

359-G

SPENCER
TURBO-COMPRESSORS

WARD TELEVISION ANTENNAS MADE
STRONGER, LONGER-LASTING,
EASIER TO INSTALL with
J&L STEEL PERMA-TUBE
J&L STEEL
The vertical mast and cross-arms of the Ward "Minute Man" antenna are made of J&L PERMA-TUBE. It takes just 60 seconds to remove the preassembled antenna from its box and swing all arms into position as shown here. PERMA-TUBE antennas combine strength, rigidity and rust-resistance—give longer *trouble-free* service—and better television reception.

PERMA-TUBE may be used for many applications where strength, rigidity, rust-resistance, and attractive appearance are necessary.

By using the new exclusive rust-resisting J&L PERMA-TUBE for the vertical mast and cross-arms in the "Minute-Man" series of television antennas, Ward Products Corporation, Division of the Gabriel Company, Cleveland, Ohio, builds-in the following advantages:

1. **Greater structural rigidity with smooth, attractive appearance. Greater strength to resist ice loads.**
2. **Clearer, steadier, television reception. Less vibration from wind.**
3. **No mechanical seam in Perma-tube to invite rust which would reduce the torsional strength.**
4. **Ease and speed of installation . . . at less cost.**

J&L PERMA-TUBE is a light-wall, electricweld steel tubing, coated inside and out with an exclusive plastic-type, weather-resistant finish. PERMA-TUBE can be furnished: bent . . . expanded . . . flanged . . . swaged or fluted.

J&L PERMA-TUBE for television antennas, *costs less than any other tubing with comparable strength, rigidity and rust-resistance.*

J&L PERMA-TUBE is not only applicable to television antennas, but also wherever strength, rigidity and rust-resistance are important. It is available in all regular sizes and shapes of J&L Electricweld Tubing and in lengths up to 10 feet. Return the coupon TODAY for complete information on this new J&L product.

Jones & Laughlin Steel Corporation
405 Jones & Laughlin Building
Pittsburgh 19, Pa.

Please send me complete information on the new J&L STEEL PERMA-TUBE mechanical tubing.

Do you recommend PERMA-TUBE for _____ ?

NAME _____

COMPANY _____

ADDRESS _____

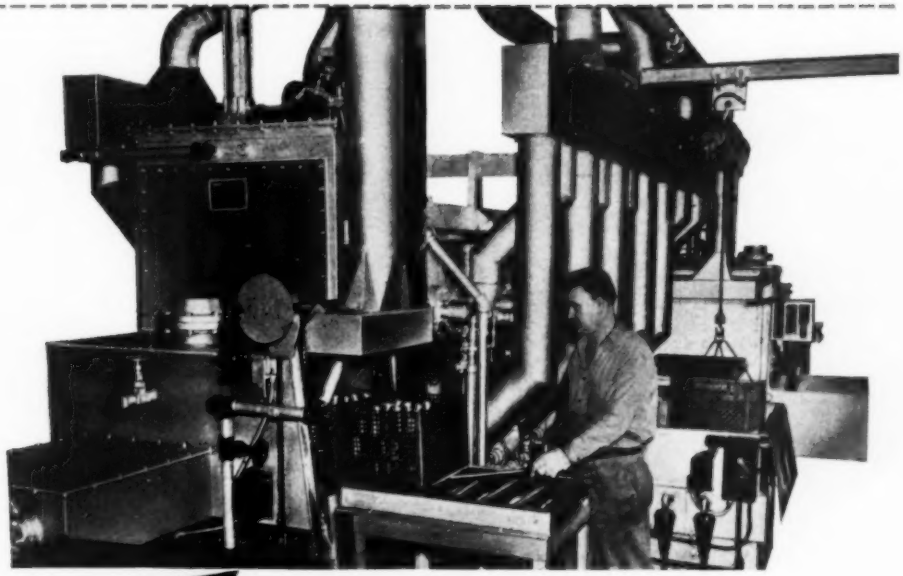
JONES & LAUGHLIN STEEL CORPORATION

From its own raw materials, J&L manufactures a full line of carbon steel products, as well as certain products in OTISCOLOY *and* JALLOY *(hi-tensile steels).*

PRINCIPAL PRODUCTS: HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURAL SHAPES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



FOR THE MAN WHO CAN'T BE SOLD

Here's the solution to your Gas Carburizing Problems

Westinghouse Therm-a-neering has the answers. This engineering and metallurgical service is offered with no obligation to the man who "can't be sold", but, who is willing to accept *proof* of efficiency and dependability. Therm-a-neering custom-builds equipment to fit your individual requirements, assuring smooth and economical operation of your heat-treating line.

Take the carburizing furnace shown above, for example: one continuous and complete operation puts all parts through the same cycle, same atmosphere, same temperature. Uniformity of parts is assured. Rejects are eliminated.

And the work is done fast. No handling of parts is required between charging and discharging. Doors open automatically. One operator handles all work easily. Production is maintained at 800 net pounds per hour.

This installation is typical of the way Westinghouse furnaces—both gas-fired and electric—are answering today's production problems. And because Westinghouse engineers have no favorite to play, they can study your problems from an unbiased point of view in helping you select the equipment to do your job most efficiently and economically.

Let Therm-a-neering help you. Call your nearby Westinghouse representative for details, or write Westinghouse Electric Corporation, 181 Mercer St., Meadville, Pa. J-10350

Therm-a-neering. **A HEAT AND METALLURGICAL SERVICE THAT OFFERS WITHOUT OBLIGATION:**

ENGINEERS—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

RESEARCH—A well-equipped metallurgical laboratory in which to run test samples to demonstrate the finish, hardness and metallurgical results that can be expected on a production basis.

PRODUCTION—A modern plant devoted entirely to industrial heating.

EXPERIENCE—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

Westinghouse

GAS AND ELECTRIC

Furnaces

Centrifugal roll—cast from Thermalloy "30".
Radiant Tube Assembly —Centrifugally cast from Thermalloy "40".
Centrifugal Retort Tubes and Locking Plugs. Thermalloy "40-B".
Roll for roller bottom furnace—Centrifugally cast body of Thermalloy "40".

Let's talk *FACTS* about CENTRIFUGAL CASTINGS

We make both centrifugal castings and static castings. We don't make a blanket claim that centrifugal castings are denser, more uniform or stronger. In certain cases, this has proved to be true. But for all practical purposes, the differences in physical properties are almost negligible.

Thinner wall sections can be produced more economically by centrifugal casting than by static casting.

The amount and location of machining must be considered. Centrifugal casting produces a smoother outside surface than static casting. However, shrinkage areas are usually found on the inside surface, making it necessary to provide more machining stock if a finished surface is required.

In some cases, costs may be lower for centrifugal castings than for static castings—but this depends entirely upon the individual casting to be produced.

We recommend that you let our experienced metallurgists work with you in selecting the most economical type of casting for your application. You may be sure of a practical and unbiased recommendation. Call your nearest Electro-Alloys engineer, or write Electro-Alloys Division, 1978 Taylor Street, Elyria.

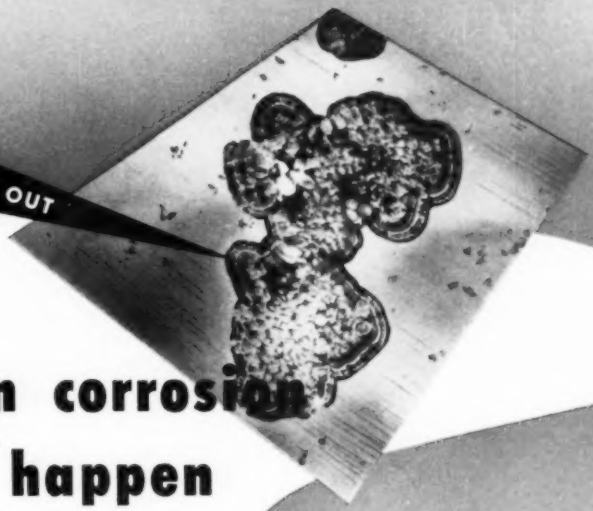
Specify CHEMALLOY* for corrosion resistance
THERMALLOY* for heat and abrasion resistance

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

WE WOULD LIKE TO POINT OUT



underfilm corrosion just *Can't* happen with

Weirzin

ELECTROLYTIC ZINC-COATED SHEETS AND STRIP

Paints, enamels, lacquers, varnishes and lithographic inks adhere to Weirzin securely and permanently, because underfilm corrosion cannot occur. The tight, malleable zinc coating, electrolytically applied, becomes an integral part of the sheet or strip . . . remains intact under all conditions of temperature and humidity . . . provides a perfect "tooth" for spray, dip or roller applications.

Extensive fabrication does not weaken this bond—after deep-drawing, forming and punching, the zinc coating remains unruptured and evenly deposited. There are appreciable savings in manufacturing, too, because Weirzin sheets and coils require no pickling or buffing, and very little cleaning . . . there is no need for a primer under paint.

WEIRTON STEEL CO.

WEIRTON STEEL COMPANY

WEIRTON, W. VA., *Sales Offices in Principal Cities*

Division of **NATIONAL STEEL CORPORATION,** *Executive Offices, Pittsburgh, Pennsylvania*

NATIONAL STEEL

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...OFFERS A COMPLETE LINE OF EQUIPMENT FOR THE Metallurgical Laboratory

Buehler specimen preparation equipment is designed especially for the metallurgist, and is built with a high degree of precision and accuracy for the fast production of the finest quality of metallurgical specimens.

1. No. 1315 Press for the rapid moulding of specimen mounts, either bakelite or transparent plastic. Heating element can be raised and cooling blocks swung into position without releasing pressure on the mold.

2. No. 1211 Wet power grinder with 3/4" hp. ball bearing motor totally enclosed. Has two 12" wheels mounted on metal plates for coarse and medium grinding.

3. No. 1000 Cut-off machine is a heavy duty cutter for stock up to 3-1/2". Powered with a 3 hp. totally enclosed motor with cut-off wheel, 12" x 3/32" x 1-1/4".

4. 1505-2AB Low Speed Polisher complete with 8" balanced bronze polishing disc. Mounted to 1/4 hp. ball bearing, two speed motor, with right angle gear reduction for 161 and 246 R.P.M. spindle speeds.

5. No. 1700 New Buehler-Waisman Electro Polisher produces scratch-free specimens in a fraction of the time usually required for polishing. Speed with dependable results is obtained with both ferrous and non-ferrous samples. Simple to operate—does not require an expert technician to produce good specimens.

6. No. 1410 Hand Grinder conveniently arranged for two stage grinding with medium and fine emery paper on twin grinding surfaces. A reserve supply of 150 ft. of abrasive paper is contained in rolls and can be quickly drawn into position for use.

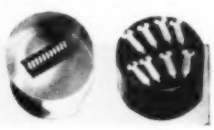
7. No. 1400 Emery paper disc grinder. Four grades of abrasive paper are provided for grinding on the four sides of discs, 8" in diameter. Motor 1/3 hp. with two speeds, 575 and 1150 R.P.M.

8. No. 1015 Cut-off machine for table mounting with separate unit recirculating cooling system No. 1016. Motor 1 hp. with capacity for cutting 1" stock.

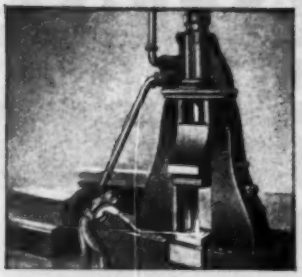
THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Buehler Ltd.
A PARTNERSHIP

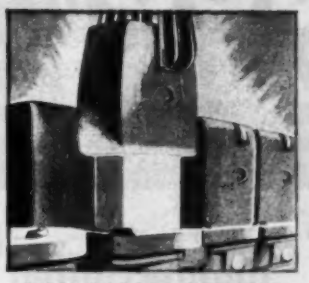
METALLURGICAL APPARATUS
165 WEST WACKER DRIVE, CHICAGO 1, ILL.



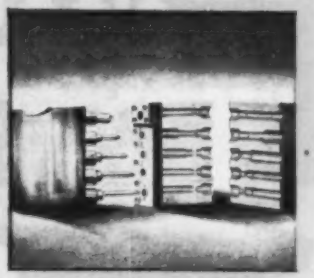
When the HEAT'S on...



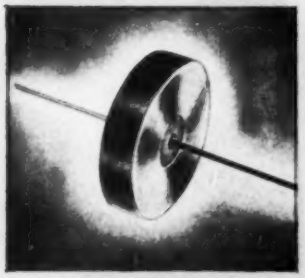
FORGING



STEEL INGOT STRIPPING

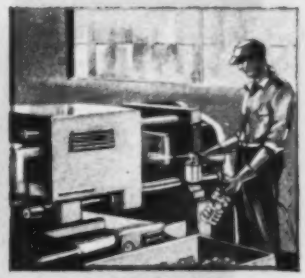


DEEP PIERCING



WIRE DRAWING

STRETCH FORMING



DIE CASTING

"dag" Colloidal Graphite Keeps 'em Lubricated!

At high temperatures . . . 400°F. and up, where ordinary lubricants begin to fail . . . **"dag"** colloidal graphite dispersions lick friction and keep parts lubricated for action.

"dag" colloidal graphite is not just ordinary graphite. It is graphite which has been processed scientifically so that its particles are usually less than .000039 inch in diameter!

This means that when colloidal graphite is applied to the friction surfaces of metal it leaves a lubricating film so thin that even the most sensitive gages cannot detect it. The film is many times more durable than an oil film. It provides the metal with a graphoid surface that has an extremely low coefficent of friction, that resists oxidation, and that will function at temperatures far above the burning point of oil.

Acheson Colloids engineers are anxious to help you with your lubrication problem. Call the local representative, or mail the coupon TODAY for more information on **"dag"** colloidal graphite dispersions.

Acheson Colloids Corporation, Port Huron, Mich.; Boston; New York; Philadelphia; Pittsburgh; Cleveland; Detroit; Chicago; St. Louis; Los Angeles; San Francisco; Toronto.

dag COLLOIDS

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Port Huron, Michigan

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It's MISCO for HEAT RESISTING ALLOYS IN ROLLED MILL FORMS

Sheets — Plates — Rounds ● Squares ■ Hexagons ⬢ Flats — Angles L
Channels U Sections Pipe ○ Nuts ◎ Welding Rod

Uninterrupted Service for 15,827 Hours

MISCO METAL *Delivers* Outstanding Carburizing Retort Performance

Typical of over 200 retorts, that have been fabricated from rolled Misco Metal, is the service record of the above carburizing retort which has outlasted every competitive heat resisting alloy, even the most costly and widely advertised. Photo, at left, shows retort at start of service *(May, 1946)*, unretouched photo, right, is same retort *(August, 1949)* after 15,827 hours of use. Note splendid state of welds and surface condition of metal. Here is proof that retorts made of Misco Metal last longer than those made of any other metal. On your next order for retorts—insist on Misco Metal for lower cost, longer life, no dissatisfaction. Your fabricator can supply it. Misco has the rolled plates in stock for immediate delivery.

ROLLED PRODUCTS DIVISION
Michigan Steel Casting Company

MISCO Heat and Corrosion Resisting Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys
1998 GUOIN STREET · DETROIT 7, MICHIGAN

Cyanide Disposal Problems Minimized

by the

UNICHROME Pyrophosphate Copper Plating Bath

S-M-O-O-T-H PLATING.
The fine-grained Unichrome deposit gives smoothness without the need for brighteners.

BUFFING TIME IS CUT.
If needed at all, buffing of the ductile, free-flowing copper takes little time, less effort.

ANODES CORRODE EVENLY.
Unichrome bath needs fewer anodes to maintain copper in solution. It keeps anodes clean and efficient.

EASILY CONTROLLED.
Unichrome Copper is stable bath, does not build up carbonate, has good tolerance for impurities.

ONE BATH FOR ALL JOBS.
It plates zinc die castings, aluminum, intricate shapes; provides suitable undercoat for nickel, chromium; stops-off for nitriding, carburizing.

Many localities already prohibit unregulated disposal of plating room wastes. More and more are taking steps to control dumping of solutions and rinse waters. Cyanide-bearing wastes such as those from cyanide copper baths are particularly critical — due to their toxicity even when greatly diluted.

Solving the cyanide disposal problem by installing a treating unit is expensive. The more cyanide you have, the greater is the expense. You can minimize this expense by using the non-cyanide Unichrome Pyrophosphate Copper plating bath, which not only is safer, but also offers outstanding advantages in operation such as those described at the left.

If you want *complete* details, showing how the Unichrome Pyrophosphate Copper plating bath can help you do a better, safer finishing job at lower cost, write us for informative literature. Or better yet, ask us to have an engineer discuss this matter with you.

UNICHROME
Trade Mark Reg. U.S. Pat. Off.

PROCESSES AND MATERIALS FOR SURFACES THAT SURVIVE

UNITED CHROMIUM, INCORPORATED

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AUTOMATIC or hand polishing . . . mounting . . . cutting-off specimens . . . all require the best in equipment and accessories.

Precision offers you a source of supply and an engineering staff to help you in solving your particular Metallurgical problems. From cut-off wheels to grind-polishing powders, a constancy is maintained in order that you may not only get the best possible results, but, **results which can be duplicated!**

A copy of our Metallurgical Catalog will provide you with information which will be most helpful. Write for your copy today.

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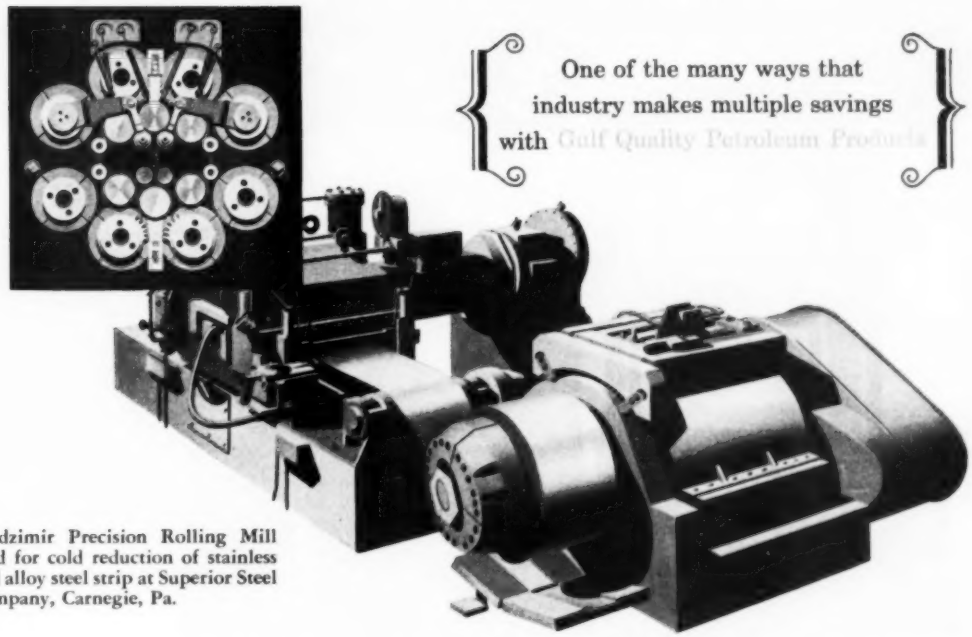
GULF STAINLESS METAL OIL

extends roll and bearing life, improves strip finish in precision Cold Rolling Mill

One of the many ways that industry makes multiple savings with Gulf Quality Petroleum Products



Sendzimir Precision Rolling Mill used for cold reduction of stainless and alloy steel strip at Superior Steel Company, Carnegie, Pa.

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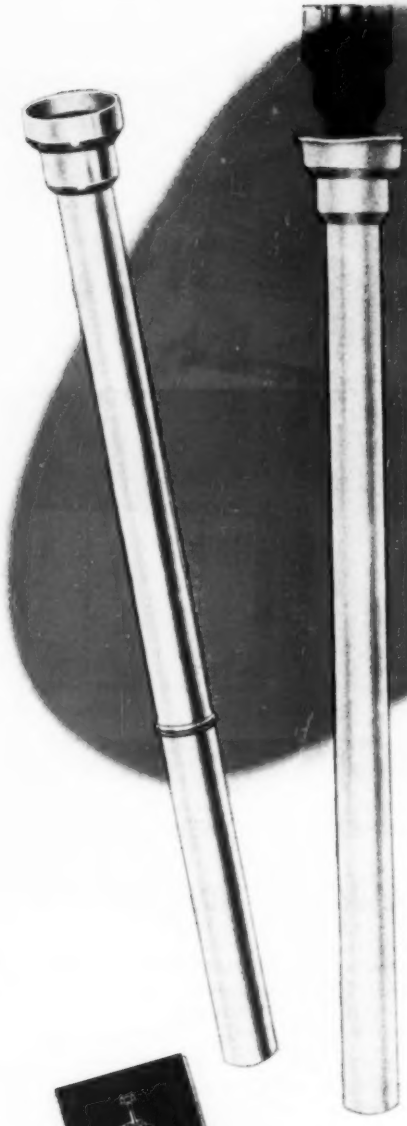

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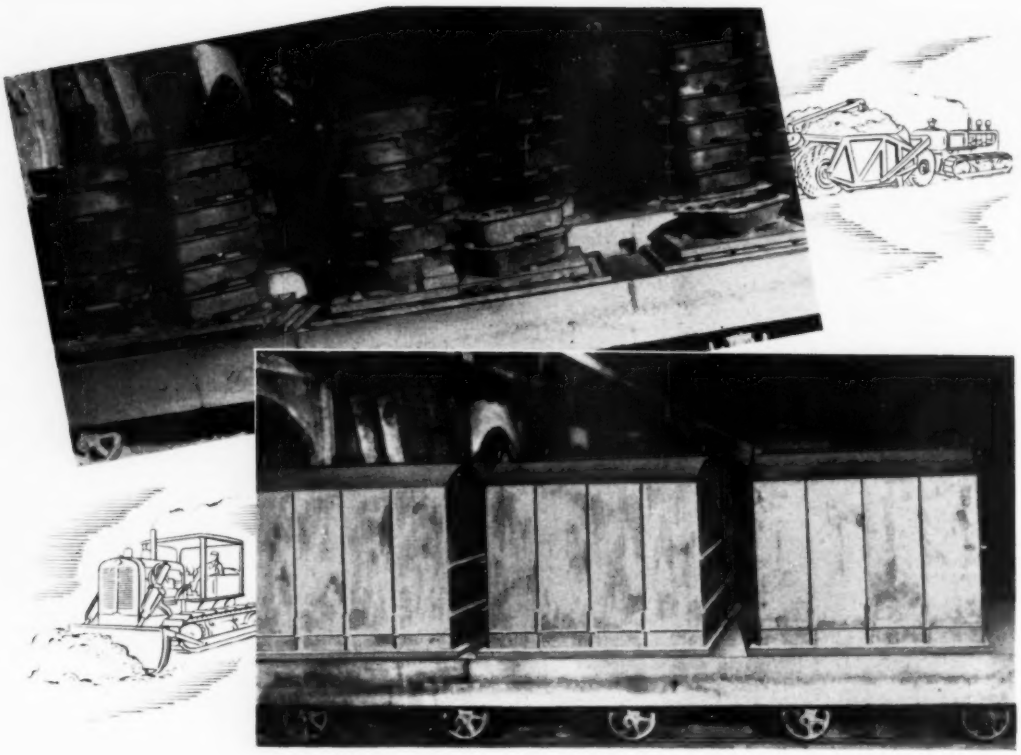

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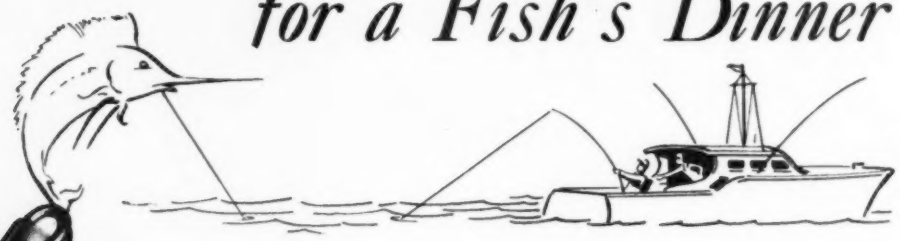

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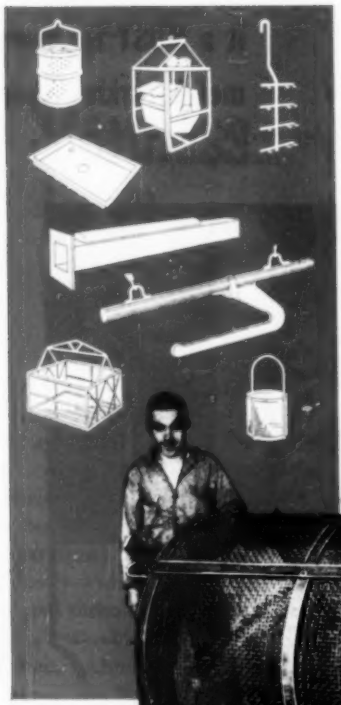

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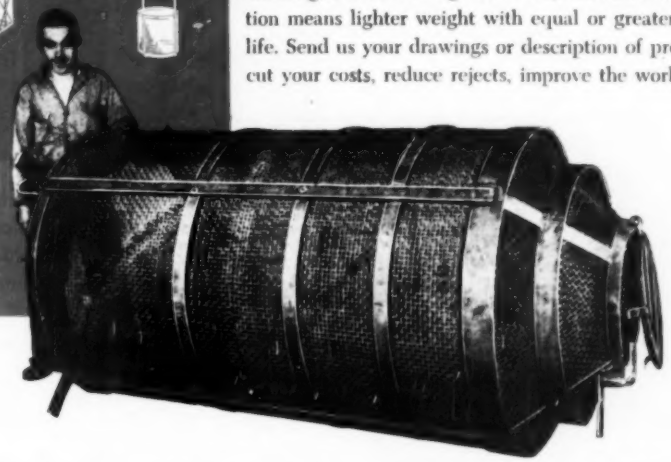

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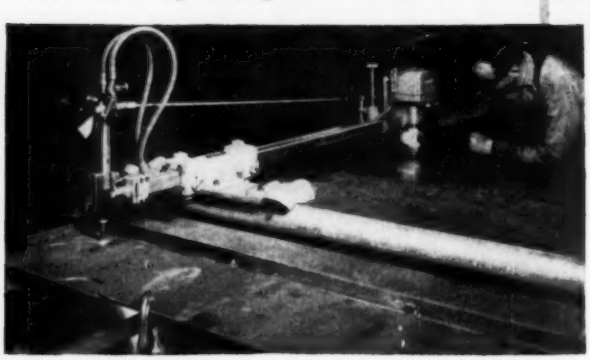

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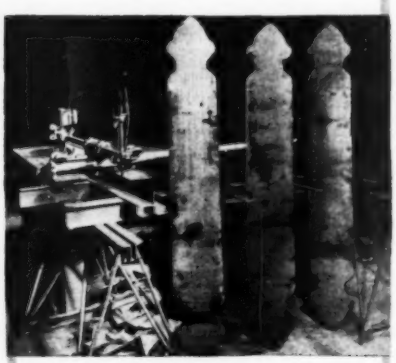

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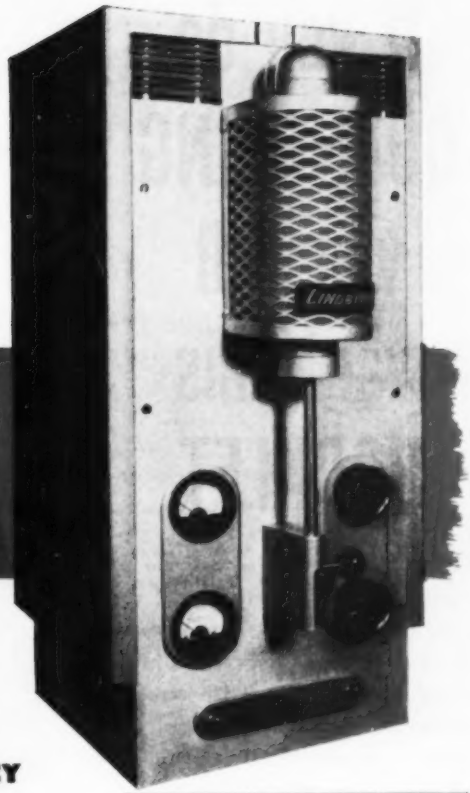

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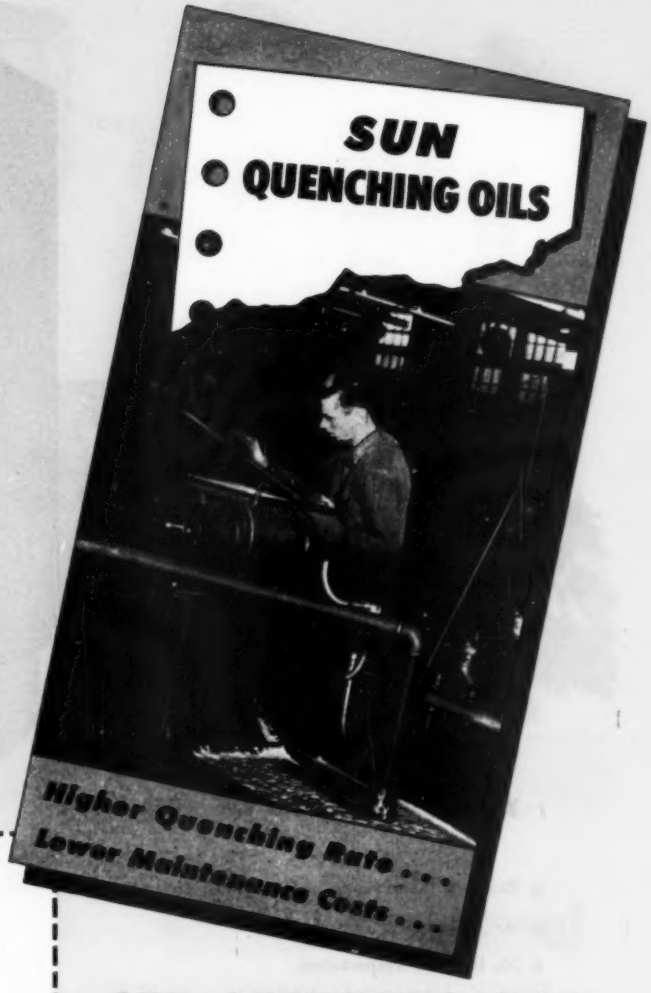

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Metal Progress

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THE LOW-ALLOY HIGH-STRENGTH STEEL

The Carbonitriding Process of Case Hardening Steel

By G. W. P. Rengstorff, M. B. Bever and C. F. Floe
Department of Metallurgy
Massachusetts Inst. of Technology
Cambridge, Mass.

CARBONITRIDING is less than two decades old as an industrial method of case hardening, but it is rapidly assuming importance, especially in the automotive industry. In contrast with this practical development, however, understanding of the structure and properties of the case produced by carbonitriding has lagged. An investigation in progress at the Massachusetts Institute of Technology is finding answers to some fundamental problems concerning the process.*

The term carbonitriding raises a question concerning the relation of this method for the surface hardening of steel to the well-known methods of carburizing and nitriding. Brief consideration of these processes is therefore pertinent. In carburizing, a layer of high-carbon steel is formed on a low-carbon base. This layer requires hardening by a heat treatment, which, however, involves no metallurgical principles not also encountered in ordinary steel treating. Heat treating problems in carburizing result chiefly from the simultaneous presence of the high-carbon case and the low-carbon core.

Nitriding differs basically from carburizing. Nitrided cases owe their hardness to the precipitation of alloy nitrides, a hardening mechanism not otherwise employed in ferrous metallurgy. Carburizing is conducted above the transformation range, at approximately 1700° F.; the nitriding temperature of 975° F. is well below the transformation range. This low operating temperature explains why nitriding is usually carried out for longer periods than carburizing. In contrast with carburizing, nitriding calls for no further heat treatment. Unalloyed low-carbon steels are suitable for carburizing, although low-alloy steels are used to increase hardenability of the case and to improve core properties. Nitriding, on the other hand, requires special steels containing elements which form nitride precipitates. Carburized parts usually undergo distortion, which must be corrected by finishing operations. Nitrided articles may also be slightly distorted but finishing serves chiefly to remove a characteristic surface layer of iron nitrides.

Carbonitriding can be defined as case hardening by the simultaneous absorption of carbon and nitrogen from a gaseous atmosphere of suitable composition, followed by cooling at a rate that produces the desired properties. The hardness of a carbonitrided case is not caused by alloy nitrides; carbonitriding therefore is not a modified nitriding, but a modified carburizing process. A case produced by liquid cyaniding has many characteristics in common with a carbonitrided case, but the two processes differ from the standpoint of operation.

Principles — Carbonitriding has been carried out under a great variety of conditions. Operating temperatures have ranged from 1200 to 1650° F. Ratios of ammonia to carburizing gas have varied from less than one-to-ten to more than ten-to-one. Oil quenching, air cooling, or even slower rates of cooling have produced satisfactory results. Why such widely varying operating conditions have been successful can be understood only from the fundamental characteristics of carbonitriding.

Carbonitrided steel hardens by the same mechanism as other quench-hardening steels — by the transformation of austenite to martensite — but in

*The experimental results reported in this article were obtained by laboratory work sponsored by the Ammonia Division of Armour and Co., Chicago.

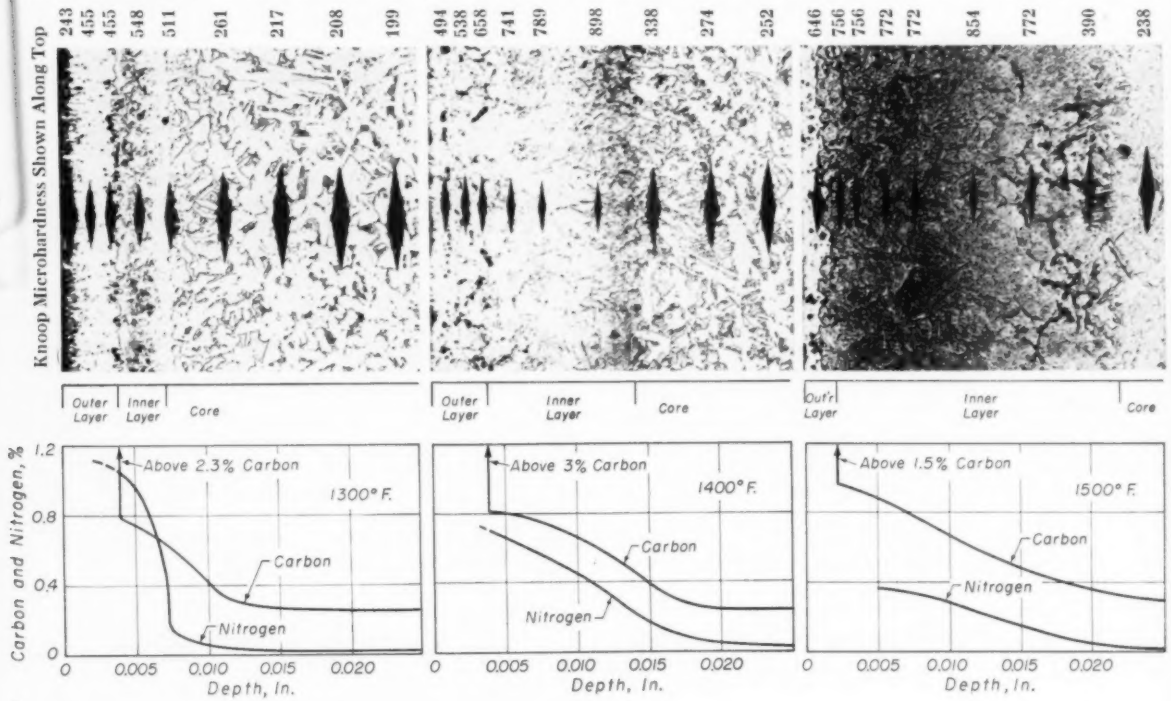
carbonitrided steel the austenite contains nitrogen as well as carbon. Carbon-nitrogen austenite differs from ordinary austenite in several respects. It is stable at lower temperatures than plain carbon austenite and transforms more slowly on cooling. Martensite therefore is obtained with intermediate rates of cooling which would produce pearlite in plain carbon steel or carburized cases. Carbon-nitrogen austenite also has a strong tendency not to transform at all on cooling, which results in the retention of austenite in the case.

The lower transformation range of carbon-nitrogen austenite allows carbonitriding to be carried out at temperatures several hundred degrees below the usual carburizing temperatures. This difference in case hardening temperature reduces grain growth, distortion and sagging. It also results in savings in fuel and furnace maintenance.

Carbonitrided cases on plain carbon steels have a sufficiently low critical cooling rate to be oil hardening. Less severe quenching than after carburizing is therefore adequate, and distortion and cracking are reduced. The increase in hardenability of carbonitrided steel permits the substitution of plain carbon for alloy steels. This increase, however, is restricted to the case; the core remains soft, which is usually desirable. In carburizing, the case differs from the core only in carbon content; in carbonitriding, nitrogen is also added and is equivalent to an alloying element. A carbonitrided carbon steel, however, differs from a carburized alloy steel in that the increase in hardenability is restricted to the case.

Nitrogen can have another effect in carbonitriding by forming carbon-nitrogen-iron compounds on the surface. The tendency to form such compounds becomes more marked with lower carbonitriding temperatures. The compound layer resembles in some ways the "white layer" formed in nitriding. The role this layer plays in service performance is not yet fully known, but probably under some conditions it contributes to the useful properties of the case.

Fig. 1 — Carbon and Nitrogen Gradients and Microstructures of S.A.E. 1020 Steel Carbonitrided at 1300, 1400 and 1500° F. for 4 Hr. in Atmosphere of 40% Ammonia, 10% Methane and 50% Carrier Gas. Micrographic specimens were quenched in oil, etched with nital, magnified 100×. Knoop microhardness indentations shown. Specimens analyzed for carbon and nitrogen were cooled in air before cutting of thin layers for chemical determinations



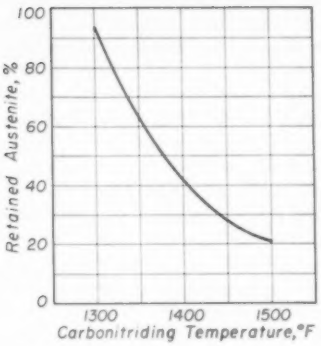


Fig. 2 — Austenite Content Just Beneath Compound Layer. Determinations by lineal analysis of specimens shown in Fig. 1

Case Compositions and Microstructures — The amounts of nitrogen and carbon in the case depend primarily on the temperature of carbonitriding. After case hardening at low temperatures, such as 1300° F., the nitrogen concentration is high, but it decreases as the operating temperature is raised. Figure 1 shows typical concentration gradients of nitrogen and carbon for three temperatures and the corresponding structures. In each of the micrographs, two distinct layers may be seen. The outer layer consists of carbon-nitrogen-iron compounds. Its thickness decreases with increasing temperature. X-ray diffraction shows that the compounds present in the outer layer change markedly with the temperature at which they form. At 1500° F. this layer is composed entirely of cementite in which nitrogen replaces some of the carbon atoms. At 1300° F. it consists primarily of hexagonal iron nitride, the epsilon phase, but some cementite is also present near the outer edge. The epsilon phase contains both carbon and nitrogen in approximately equal amounts. At 1400° F. the X-ray pattern of the outer layer is similar to that for cementite but the structure is greatly distorted. The inner layer of the case in each of the micrographs of Fig. 1 is made up of mixtures of martensite and retained austenite. The amount of retained austenite decreases as the carbonitriding temperature is raised, as shown in Fig. 2.

The compound layer formed at 1300° F. and the inner layer formed at all temperatures change in composition and structure with depth. The nitrogen and carbon concentration gradients, shown in Fig. 1, are of particular importance in the inner layer because nitrogen and carbon determine the proportions of

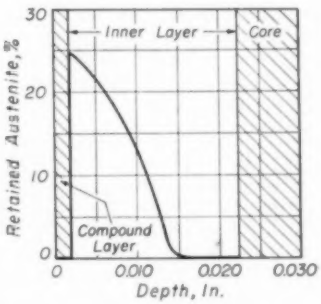


Fig. 3 — Gradient of Retained Austenite in the Specimen Carbonitrided at 1500° F. and Shown in Fig. 1

martensite and retained austenite present. An example of the decrease of retained austenite with depth in the inner layer is given in Fig. 3; this replacement of retained austenite by martensite with increasing depth may well be one of the characteristic features of carbonitrided cases.

The microstructures in Fig. 1 were obtained with oil quenching but similar structures form in thin specimens on air cooling.

Properties of the Case — Any process of case hardening is expected to increase resistance to wear and penetration. As wear resistance is difficult to measure, cases are commonly evaluated by hardness tests, which may be carried out in several ways. Surface hardness approaches most nearly the usual service conditions. Depth hardness may be measured on a tapered specimen. Microhardness testing on a section through the case allows measurement of the true hardness of the structure at different depths (Fig. 1).

The surface hardness of carbonitrided cases after quenching depends on the ratio of martensite to austenite in the inner layer and on the thickness and nature of the compound outer layer. The thick compound layer formed at 1300° F. is only moderately hard and the amount of retained austenite in the inner layer is large. As the carbonitriding temperature is increased, the thickness of the compound layer diminishes and its true hardness, measured by a microhardness tester, is higher. At 1500 to 1550° F. the compound layer may disappear entirely. These changes in the outer layer and the increase in martensite in the inner layer combine to cause an increase in hardness with carbonitriding temperatures. Figure 4 shows surface hardness for various carbonitriding temperatures.

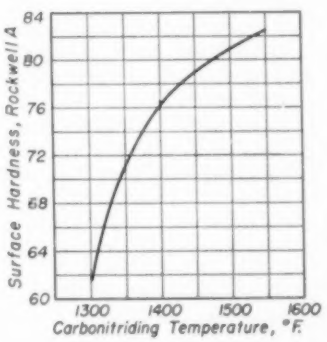


Fig. 4 — Surface Hardness of 1020 Carbonitrided 4 Hr. at Various Temperatures and Oil Quenched

Carbonitrided cases formed at high temperatures resemble carburized cases in the hardness attained and in the microstructures which cause this hardness. At lower temperatures, however, a case having useful properties can be produced by a method of hardening peculiar to carbonitriding. Such a case has a thick compound layer at the surface, even though cooling is so slow that the austenite in the inner layer transforms to a soft product.

Some carbonitrided parts are tempered to improve the properties of the core. Such tempering also affects the case; martensite in the inner layer is tempered and retained austenite may transform. The compound layer produced at 1300° F. undergoes appreciable hardening if tempered at 400 to 600° F.; this appears to be a precipitation hardening phenomenon. Tempering changes very little the compound layer formed at 1400° F. or above. As shown in Fig. 5, cases carbonitrided at the usual operating temperatures of 1500 to 1550° F. are somewhat more resistant to tempering than carburized cases, perhaps because of retained austenite.

Among the claims made for carbonitrided cases is their good wear resistance, which is confirmed by service performance. Any superiority in wear resistance of carbonitrided cases over carburized cases can probably be attributed in part to retained austenite. The wear behavior of carbon-nitrogen martensite may also differ from that of plain carbon martensite.

Improved corrosion resistance has also been claimed for carbonitrided surfaces. Any improvement is probably due to the presence of the compound layer, which has been found to resist etching in metallographic specimens.

Temperature and Duration of Carbonitriding

The major process variables of carbonitriding are temperature, time, and gas composition. Of these, temperature has perhaps the most important effects on the case. As the temperature is raised, the total depth of the case produced in a given time increases, but the relative thickness of the compound layer decreases; the nitrogen content of the compounds in the outer layer and of the austenite in the inner layer also decreases. This decrease lowers the hardenability but it also reduces the amount of retained austenite. The surface hardness of the case produced at high temperatures is therefore usually greater than for cases produced at lower temperatures.

Industrial experience indicates that cases produced above 1450° F. best withstand severe service conditions. It has also been found that carbonitriding at these temperatures produces more uniform cases and that less rigid control is required to obtain satisfactory results consistently. Temperatures in the range of 1200 to 1400° F. are occasionally used to reduce distortion or to produce the compound layer. The most common temperature range in industrial production, however, is 1500 to 1550° F.

In industry the time cycle of carbonitriding is usually shorter than that of carburizing. Although the rate of carbonitriding is slower because of the lower operating temperatures, the resulting thin carbonitrided cases are satisfactory for several reasons. Since the process causes less distortion, less material needs to be sacrificed in finishing to final tolerances, and frequently no finishing operations are necessary. Also, the applications for which carbonitriding is most suitable require only thin cases. Carbonitriding periods of less than one hour have been used successfully. Figure 6 shows the typical depth of case as a function of time at 1500° F.

In a two-stage process, carbonitriding is first carried out at 1500° F. or higher, followed by a period usually of short duration at a temperature

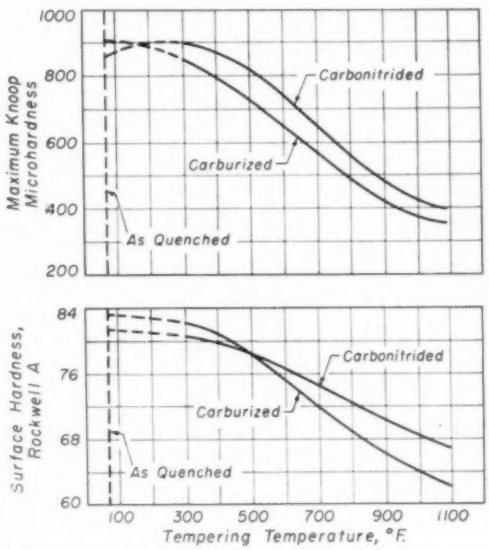


Fig. 5 — Comparison of Effects of Tempering Carbonitrided and Carburized Cases. Carbonitrided specimen was produced at 1500° F., as in Fig. 1. The other specimen was S.A.E. 1020, carburized in 10% methane and 90% carrier gas at 1700° F. to the same thickness of case as the carbonitrided specimen, and then water quenched. Duration of tempering was 2 hr.

of 1375° F. or lower. It has been argued that the first period leads to rapid absorption of carbon and the second favors the introduction of nitrogen because of reduced thermal decomposition of ammonia. Actually, at the low temperature a thicker compound layer tends to be built up without appreciable increase in the nitrogen content of the inner layer. Advantages of the two-stage treatment lie in the reduction of distortion, the production of a softer core structure and the possible decrease of retained austenite in the inner layer.

In carbonitriding, both carbon and nitrogen diffuse into the case of a steel part while it is being heated in a gas carburizing atmosphere that contains ammonia. The carbonitriding process can be substituted for carburizing or liquid cyaniding, and it can be used to case harden parts not normally case hardened by any other method. This article presents the first systematic data concerning the effects of temperature and time on the composition and structure of the carbonitrided case. Some effects of variation in the gas composition are also considered here, and the advantages of carbonitriding over other case hardening processes are discussed.

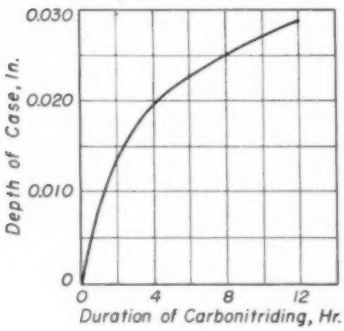


Fig. 6 — Typical Case Depth as a Function of the Duration of Carbonitriding. S.A.E. 1020 specimens were carbonitrided for various times at 1500° F. under the conditions of Fig. 1

Atmospheres for Carbonitriding

Gas composition is the most elusive of the variables of the process, chiefly because the atmosphere introduced into the furnace changes in composition even before it reaches the surface of the work. This change results mainly from the thermal decomposition of ammonia, the rate of which is affected by temperature, gas flow, dilution, and catalytic effects. The extent to which this decomposition takes place cannot be predicted. For this reason, the optimum amount of ammonia in the inlet gas cannot be calculated but must be found by trial and error. It should not be concluded, however, that the choice of an atmosphere for adequate performance is particularly difficult. Indeed, a strong point in favor of the carbonitriding process is that a satisfactory case can be produced with any one of many gas mixtures. The furnace atmosphere can be varied over wide limits without appreciably altering the nature of the case.

Any gas or mixture of gases suitable for carburizing may be used as a source of carbon in carbonitriding. The usual carburizing agents are hydrocarbons. Like ammonia they undergo thermal decomposition, although to a lesser extent. One product of this decomposition is soot, which may become troublesome but can be reduced to a harmless level by dilution of the gas.

If a simple mixture of ammonia and a hydrocarbon gas such as natural gas is used, a large excess of ammonia is required in order to combat sooting. A satisfactory gas mixture for this type of operation is 70% ammonia and 30% natural gas (methane). If other carburizing gases are used, their ratio to ammonia should be adjusted in accordance with their carburizing power. One part propane, for example, may be substituted for 2½ parts methane, resulting in a carbonitriding mixture of 85 to 90% ammonia and 10 to 15% propane. Most of the ammonia decomposes to nitrogen and hydrogen, which act as diluents for the carburizing gas.

In gas carburizing a specially prepared, nearly inert gas is commonly used as a diluent. Such a carrier gas is also suitable for carbonitriding and may be cheaper than excess ammonia. The carrier gas tends to prevent the decomposition of ammonia as well as of the hydrocarbons. If a carrier gas is used, the ammonia in carbonitriding atmospheres ranges from 10 to 40% and the methane from 3 to 10%. Any composition within this

range is likely to produce satisfactory results but the optimum mixture for a given operation can be worked out only by gradual adjustments.

Because of thermal decomposition the effective gas composition within the furnace depends largely on the rate of flow. An increase in the rate of flow allows a reduction of the ammonia content of the inlet gas. The size and shape of the furnace and the density of the charge also affect the ammonia requirements. In many furnaces ammonia is introduced at several points.

Water vapor has a very detrimental effect on carburizing, and control of the dew point of the gas mixtures used is essential. The role of water vapor in carbonitriding is not yet fully clarified. In the research carried out by the authors this problem was investigated with three gas mixtures of different water vapor content. These mixtures produced similar microstructures and the microhardness values measured across the three cases were comparable. Under the experimental conditions used, therefore, water vapor did not have any significant effect, but a general conclusion in this sense must await further research.

It has been found that small additions of ammonia, amounting to only 1 or 2%, are beneficial in carburizing, probably because ammonia counteracts the effects of water vapor and carbon dioxide. These small additions of ammonia constitute an interesting development in carburizing practice, but they are not to be considered as a form of carbonitriding.

Applications of Carbonitriding

Carbonitriding has three principal fields of application: It can be substituted for carburizing, it can replace liquid cyaniding, and it can be used to case harden parts which are not normally case hardened because of cost or for physical reasons.

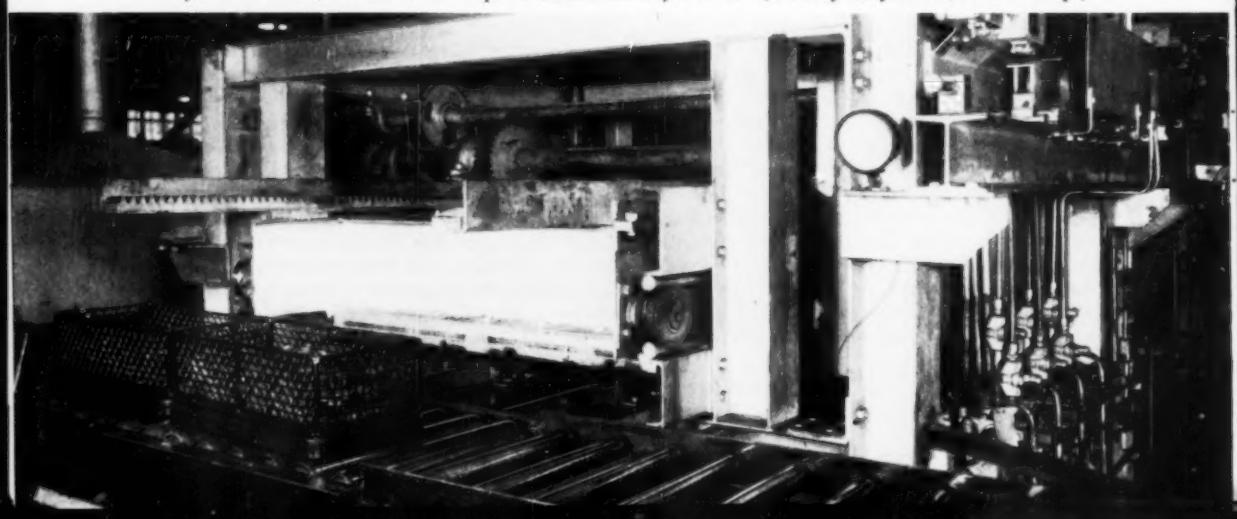
Carbonitriding has some advantages over carburizing. It causes less distortion because of a lower operating temperature, a narrower temperature interval for hardening, and a less severe quench. Carbonitriding also permits the use of plain carbon steels in place of alloy steels. Since carbonitriding usually results in a hard case and soft core directly after quenching, auxiliary heat treatments often necessary after carburizing are not required. It is also likely that carbonitrided cases have better wear resistance and corrosion resistance than carburized cases. Disadvantages of carbonitriding are the greater cost of the atmospheres and the slower case hardening rate. Carbonitriding is not likely to be used whenever a thick case is desired.

In comparing the competitive position of carbonitriding and cyaniding, operating characteristics and costs of the two processes are the important factors. If the volume is large, carbonitriding gives lower unit costs. Working conditions are usually better in carbonitriding than in operations involving liquid baths. Carbonitriding also produces a more uniform case on intricate parts such as those having deep threads. For selective hardening, however, liquid cyaniding may be preferable.

Some small mass-production items such as lock washers or mill wire products which cannot be case hardened economically by traditional methods may be carbonitrided. Liquid cyaniding would be satisfactory for most of these parts, but cost precludes its use. Carburizing is not well suited for these applications because of excessive distortion or the need for auxiliary heat treatments.

Considerable expansion has already taken place in the use of carbonitriding, and this process will probably become even more important in the future.

Discharge End of Continuous Furnace for Carbonitriding Automotive Parts. Pusher-type furnace, heated by radiant tubes, has automatic oil quench, wash and tray return. (*Courtesy Surface Combustion Corp.*)



Atomic Energy for Aircraft Propulsion

By Lawrence R. Hafstad*

AFTER CITING some generalizations indicating that each atomic bomb is worth hundreds of millions of dollars in shortening or preventing wars, Mr. Hafstad said that "we should think twice or maybe even three times before permitting too casual diversions of fissionable material from the stockpile for generating commercial power or even for other conceivable military uses. It follows also that this is indeed a game in which if we are to play at all, we play with 'blue chips'.

"In view of the serious limitations of chemical fuels, the desirability of an ideal nuclear power plant for aircraft is obvious, and I can quote the 'Brewster report' to Congress: 'In the event of war or in any international situation likely to lead to war, nuclear energy for the propulsion of aircraft would be comparable in significance to the atomic bomb itself.'

"With the desirability of an ideal solution to this problem [of nuclear propulsion of aircraft] there is general agreement. There is agreement too that developing any kind of an aircraft reactor will be extremely difficult. The 'NEPA Project', carried out by the Fairchild Co. at Oak Ridge, Tenn., under an Air Force contract, has been engaged in a vigorous attack on this problem since 1945. The North American Aviation Co. and the 'Rand Project' have also made important contributions. These studies all seem to indicate that, granting the difficulties of design and construction of the reactor itself, the problem of converting its heat into power represents a challenge of almost equal magnitude.

"As seems to be characteristic of this field of activity, anything which is obviously desirable and important seems to be almost incredibly difficult! To help resolve the impasse, the Atomic Energy Commission contracted last year with Massachusetts Institute of Technology to make a study; it came up with the 'Lexington report', recommending that the aircraft propulsion project should be continued in an intensive study phase, both theoretical and experimental, for the next two or three years, by which time data might become available to permit a re-evaluation and a more decisive conclusion. It recommended that this study should be national in scope; it now includes the Air Force, the Navy Bureau of Aeronautics, the National Advisory Committee for Aeronautics and the Atomic Energy Commission.

"In the meantime, in accordance with the Lexington report's recommendations, the National Military Establishment has been asked to evaluate the military worth of the proposed weapon [nuclear propelled aircraft] if and when it is produced. This is a really tough assignment. It is indeed controversial, but not in the sense of an interservice feud. Both the Air Force and the Bureau of Aeronautics want nuclear-powered airplanes if at all possible, and so long as the Atomic Energy Act is in existence neither can hope to build a private empire in this field even if it so desired. The issue rests on the typical, perplexing, circular hen-and-egg nature of decisions involving new weapons: How valuable nuclear-powered aircraft might be depends heavily upon when it will be available, what the maintenance problems are, what the cost will be in diversion of fissionable material, not only for the aircraft reactors installed but also for the inventory required by the complex reprocessing procedures required for nuclear fuels. Unfortunately, the answers to these questions depend on the priority which is attached to the development program.

"The dilemma is very real and very serious. It was to aid in solving just such problems that the Weapons Systems Evaluation Group was set up in the National Military Establishment.

"The best summary of the situation which I can give is that the pessimists, who in general are those best informed, have thought through the immediate reactor and power-transfer problems and are staggered by the maintenance and operations problems which would be involved if the actual aircraft propulsion devices for combat use were to be based on our present knowlegde and practices. The optimists, on the other hand, either are not yet aware of the very real immediate difficulties or they are betting heavily on new ideas and new developments arising during the course of the work which avoid some of the currently foreseeable troubles. This is an area in which it will no doubt be wise for us to be open-minded but skeptical. In this connection, I seem to recall that not many years ago all the technical facts, and all the arguments of the experts, indicated an upper limit of 100,000 lb. as an absolute ceiling for the size of heavier-than-air craft!

"Now as to the question as to whether our objective is worth while, and whether we have a sound approach:

"We want to maintain technical leadership in the atomic energy field. As part of this effort we want a vigorous reactor program. This program must earn its keep for either peace or war purposes. The initial part of this program is the same whether the ultimate use of the reactors developed is civilian or military. We have a generously supported applied research program in the large national laboratories, to give us basic information for new developments and for providing a trained *cadre* of specialists in the atomic energy field. We have engineering task forces attacking some of the most promising possibilities. Most urgent are the two premium fuel uses of interest to the military, namely, power for ships and power for aircraft. The first of these, while difficult, can conceivably be attained by the direct frontal attack [now being made under contract by Westinghouse]. The second is being attacked indirectly with the materials testing reactor [to be constructed at the new research center in southern Idaho], representing an important, exploratory advance as well as providing an almost essential research tool."

*Director of Reactor Development, U. S. Atomic Energy Commission. Excerpts from address before Institute of Aeronautical Sciences, Los Angeles, July 22, 1949.

By Heinrich Adenstedt
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Creep of Titanium at Room Temperature

THE investigation of creep at room temperature was started at the Materials Laboratory, Air Materiel Command, when it was learned from stress-corrosion tests that titanium samples loaded to 90% of the yield strength broke within one week, showing the normal amount of elongation but no corrosion.

Table I presents the chemical compositions and mechanical properties of the Remington titanium sheet used for this investigation. Titanium No. 1 and 2 are different melts; No. 3 is the same as No. 2, but with additional vacuum annealing, for 15 min. at 1505° F., at the Materials Laboratory. No. 1 is the identical material used for determination of the loading and unloading stress-strain curves presented by F. B. Fuller in *Metal Progress* for September; No. 1 and 2 were also used to determine the flexural fatigue values reported in that paper.

Small specimens with a 1-in. gage length and a gage cross section 0.250 x 0.064 in. were used in determining creep characteristics. Olsen strain gages were used for the higher loads and Huggenberger extensometers for the lower loads. All tests were conducted at room temperature. Figure 1 shows some of the creep curves for the annealed sheet, and Fig. 2 presents similar data for the cold rolled titanium No. 2. As may be seen from these two figures, the annealed titanium showed creep at all loads corresponding to 60 to 90% of the yield strength of the samples concerned. The creep rate of titanium No. 3 (the vacuum annealed material) loaded to 60% of the yield strength is still high, considering the low load level. In the cold rolled titanium No. 2, creep seems virtually to stop at loads corresponding to 80% of the yield strength of that material.

Figure 3 presents the variation of the creep rate with the loading time for some of the tests

Table I — Composition, Condition and Properties of the Commercially Pure Titanium Tested for Creep

Ti No.	Condition	Composition	Vickers Hardness (20 kg.)	Direction of Rolling	Yield Strength	Tensile Strength	Elongation
1	Large sheet, annealed, 0.061 in. thick	0.42 C; 0.046 N; 0.005 S; < 0.05 W; Al, V, < 0.01 each; Si, Fe, Mn < 0.03 each	257	Longitudinal Transverse	78,750 psi. 84,000	95,800 psi. 94,400	23.0% 24.5
2	Strips, cold rolled, 0.066 in. thick	0.34 C; 0.091 N; 0.005 S; < 0.05 W; Al, Cr, V < 0.01 each Si, Fe, Mn < 0.03 each	287	Longitudinal Transverse	100,400 104,100	116,800 119,500	11.5 18.5
3	Strips, cold rolled, 15-min. vacuum anneal at 1505° F.	Same as No. 2	258	Transverse	87,900	102,300	21.0

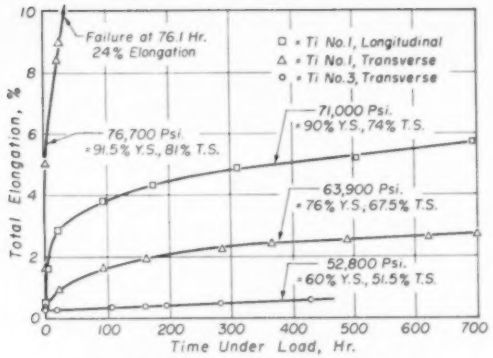


Fig. 1 — Creep of Annealed Titanium Sheet at Room Temperature

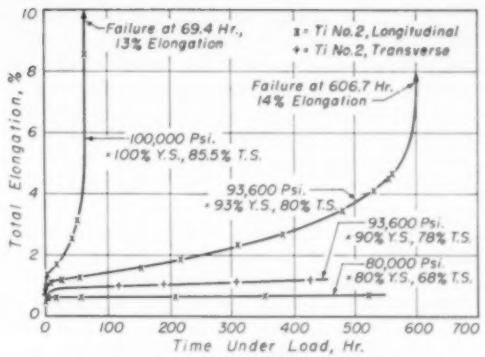


Fig. 2 — Creep of Cold Rolled Titanium Strip at Room Temperature

plotted in the first two figures. The creep rate decreases very rapidly after the load is applied (first stage of creep), reaches a minimum and stays constant or nearly constant for a certain time (second stage) and increases rapidly to high values until the sample fails (third stage). Since knowledge of the secondary (or minimum) creep rate is very important as a criterion of the long-time creep behavior of a sample, and since only a limited test program could be conducted, the following procedure was used:

One test on titanium No. 1 with a load equal to 76% of the yield strength was continued for 1600 hr. The creep rate decreased for about 600 hr. and stayed nearly constant for the next 1000 hr., varying only slightly according to variations in room temperature. Therefore, this final creep rate was considered as the true minimum creep rate. For this and all the other tests, it was concluded that a test duration of about 700 hr. is sufficient to approach the true minimum creep rate with a high enough degree of precision.

Figure 4 summarizes the results of all tests conducted and compares them with creep rate curves observed by other investigators. The data shown for aluminum alloys were obtained from an unpublished report dated November 1947, "Creep and Stress-Rupture Investigations on Some Aluminum Alloy Sheet Metals", by J. E. Dorn and T. E. Tietz, Department of Metallurgy, University of California (Berkeley), under the sponsorship of the Aluminum Company of America. The data for

Fig. 3 — Variation in the Creep Rate of Titanium at Room Temperature

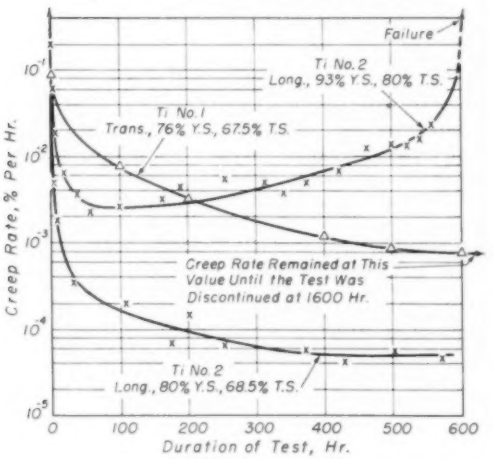
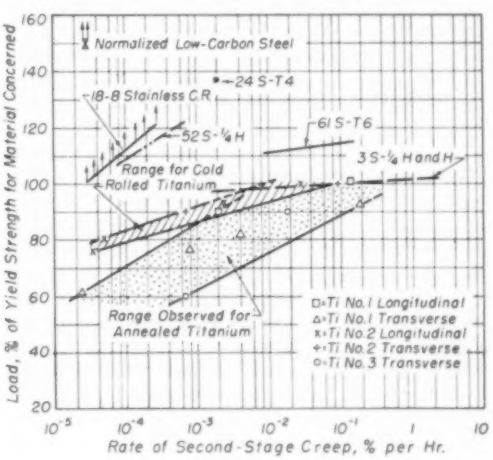


Fig. 4 — Comparison of Minimum Creep Rates of Titanium and Other Structural Metals



steel are from "Creep Phenomena of Steel at Room Temperature", by A. Pomp and A. Krisch, *Mitteilungen aus dem Kaiser-Wilhelm Institut für Eisenforschung, Düsseldorf*, Vol. 26, 1943, p. 59-69.

The following conclusions can be drawn from the data displayed in Fig. 4:

1. The annealed titanium sheet showed the highest tendency for creep. The creep rates scatter over a wide range, indicating that perhaps other factors (grain size, orientation, residual stresses) have an important influence.

2. By cold rolling, not only the yield strength of the titanium is increased, but also the creep behavior is improved. For instance, a load equal to 80% of the yield strength produces a creep rate of 0.0001% per hr. in the cold rolled titanium, while loads of only 50 to 60% of the yield strength give the same creep rate in the annealed material.

3. None of the other structural materials used for comparison in Fig. 4 show dangerous secondary creep when loaded to produce stresses less than the corresponding yield strength; therefore, designing to stresses below the yield strength will avoid dangerous creep in these common structural alloys.

4. For titanium, the consideration of the yield strength by the designer is not sufficient to avoid failures, especially if static loads of long duration are applied. In designing for titanium, it will be necessary to determine so-called design curves, such as are usual for elevated temperature application of all structural materials, and for zinc alloys at room temperature.

Although the creep tests revealed a very unfavorable property of titanium that was not anticipated for this metal with a high melting point (~3200° F.) and a high recrystallization temperature (>800° F.), the creep behavior should not be considered too discouraging for a practical application of the new metal titanium. In many practical applications, the part concerned is not permanently loaded close to the yield strength of the material, but the high load is applied only over short time cycles and may, therefore, not cause excessive creep and failure during the lifetime of the part. Also, titanium will be used mostly in the cold worked condition, because of the higher strength of the metal as cold worked, and the creep can be stopped by a relatively small reduction of the allowable stresses.

In the future, titanium *alloys* probably will have a greater importance than the commercially pure metal, and there is some hope that these alloys will show a more favorable creep behavior than the metal. Also, heat treatment (for instance, precipitation hardening) of a titanium alloy may produce favorable conditions.

Photograph in the Sauveur Collection, A.S.M.

Floris Osmond

1849-1912

IT IS QUITE appropriate, in an issue of *Metal Progress* primarily devoted to metallographic methods, to salute the memory of Floris Osmond, born 100 years ago in Paris. Educated at Ecole Centrale, he studied metallurgy, as it was then taught, and spent the next ten years in steel plants at Denain and Creusot. He then returned to Paris and henceforward devoted himself to the scientific study of iron and steel in the Sorbonne laboratories of Professor Troost and in another installed at his home.

Aside from the fundamental work on allotropy — and his penetrating mind may be appreciated from his association of alpha and gamma iron with different space lattices in 1996, long before X-ray diffraction methods — Osmond was a master metallographer. Probably his widest-known work was his account of his microscopic methods. This 1895 paper contains the first photographs and descriptions of the structures in hardened steel, named by him after his forerunners Martens, Troost and Sorby. He favored the method of relief polishing; the micros accompanying this first publication could find an honored place in the 1949 Metallographic Exhibit; indeed they were not surpassed until a later generation of instrument makers constructed metallographic microscopes of greater precision.

Metallography at Mid-Century

IF Floris Osmond had lived to be 100, he would have seen more and better micrographs. He would have seen the microscope used for the control of metal working operations. And he would have seen well substantiated explanations for the occurrence of some of the microconstituents that he discovered and named. He would have seen these things happen in many countries.

On the centenary of Osmond's birth, it is appropriate to recall the international character of metallography. In the early 1900's metallographists had a strong incentive to be international — there were only a few of them and they worked in different countries. Osmond strengthened those ties when he named three new microconstituents in steel — martensite, troostite and sorbite — after a German, a Frenchman and an Englishman. Metallography remains international. The most recent reminder of this fact is the 1949 A.S.M. Metallographic Exhibit, at which five of the twenty-two awards went to Europeans.

Since Osmond's death in 1912, metallography has become widespread. All metallurgists study the subject and most other engineers get a smattering of it in school. In addition, there is a large and growing body of those who specialize in preparing metal specimens and photographing them at high magnification. These technicians, craftsmen, artists — call them modern metallographers — have taken over much of the detailed work in microscopy of metals; the clarity and fidelity of contemporary micrographs are in large part a tribute to their careful work.

Metallography at mid-century has, then, a large and vigorous membership. It has also a large clientele — the production, design, development and research engineers who want to see how their problems look through a microscope. How potent an aid this has become is apparent to anyone who reads the technical publications of 50 years ago, wherein multiple inferences are marshalled to support an idea that could later be proved or disproved by one glance through a microscope. Some of the modern problems are no great strain on the metallographer; he can check case depth and grain size with his eyes closed (one eye anyway). But even in a duty so apparently routine as grain size determination there is still room for progress, as is pointed out in the article on p. 692 of this issue.

Other problems are less susceptible to standardized solutions. For instance, when metals crack during service or fabrication, the metallographer is likely to get a chance to do his stuff, and frequently he comes up with the answer through some innovation in metallographic practice. This type of problem is well illustrated by the article on p. 681.

Even the designer, working with dimensions far above the microscopic, may need the direct assistance of the metallographic laboratory, as in the problem of heat flow through rocket motor walls, described on p. 685.

The development of new and better metals and alloys provides a continuing stimulus to metallography. Here the metallographer is left largely to his own resources (or *her* own resources — to recognize more explicitly the feminine metallographers, of whom two are contributors in this issue). This "new metals" branch of the fraternity (and sorority) is represented in these pages by the interesting contributions on uranium (p. 662), beryllium (p. 664), indium (p. 666) and zirconium (p. 667).

Not only new metals, but also new techniques for old metals are discussed in this issue of *Metal Progress*: Cathodic vacuum etching for both macro- and micro-examination of difficult specimens, p. 674; the electron microscope, no longer a novelty but still easier to classify as new rather than old, p. 670; "obverse and reverse" fractographs, p. 672; and electropolishing, p. 696.

The microscope has become indispensable in industry. But whatever may be said of its usefulness in solving practical problems, the greatest power of metallography remains, as in Osmond's time, in the basic study of metal structure — in metal science. However, there is an important difference now. X-ray and electron diffraction, nonexistent in 1912, have given more precise meaning to the results of conventional metallography. The close combination and coordinate use of several methods — optical and electron microscopy with X-ray and electron diffraction — is the metallography that will solve leftover problems and open new vistas in metal science.

All Micrographs Are Shown at 100 Diameters

Microstructure of Uranium

By H. P. Roth
Massachusetts Inst. of Technology
Cambridge, Mass.

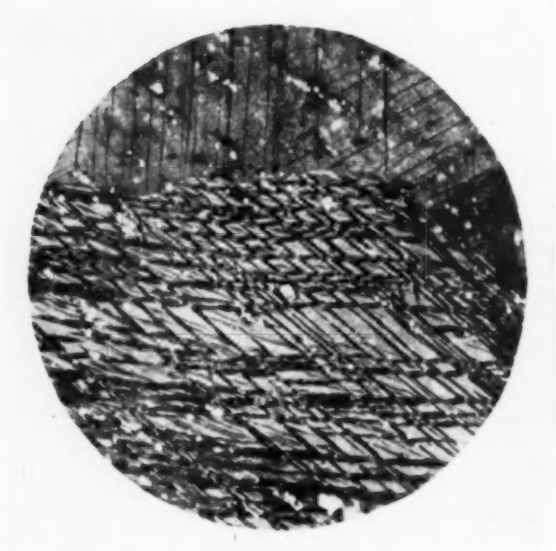


Fig. 1 — As Rolled at 500° C. (19% Reduction)

FIGURES 1, 5 and 6 are interesting examples of recrystallization occurring along deformation bands. Figure 1 shows deformation bands at varying stages of progress and along definite crystallographic planes within each grain. Figure 5 shows recrystallization beginning along one deformation band within a single large grain. The last micrograph, Fig. 6, represents the process as it nears completion. Figure 4 is typical coarse-grained beta uranium.

EDITOR'S NOTE: At the A.S.M. Metallographic Exhibit last month, the six micrographs of uranium printed here were judged Best in Class among all the entries representing heavy nonferrous metals. The same metallographer, H. P. Roth, won first place in the light metals division also, with a particularly striking picture of beryllium. A complete list of those who were awarded prizes at the 1949 Metallographic Exhibit will be published in the November *Metals Review*.

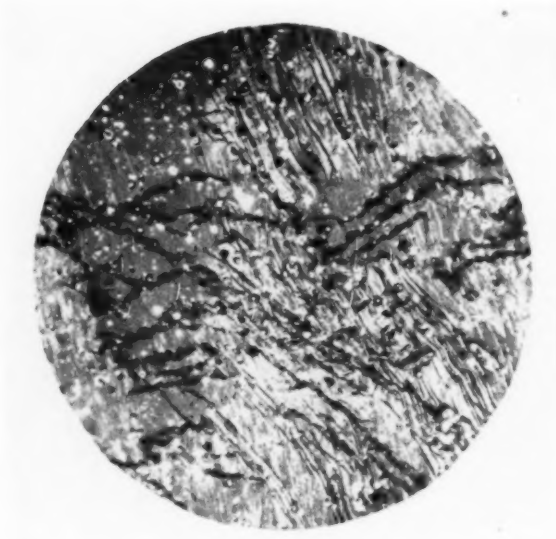


Fig. 2 — Extruded (2:1 Reduction Ratio); Annealed at 300° C.

Specimens Were Polished Electrolytically and Photographed With Polarized Light

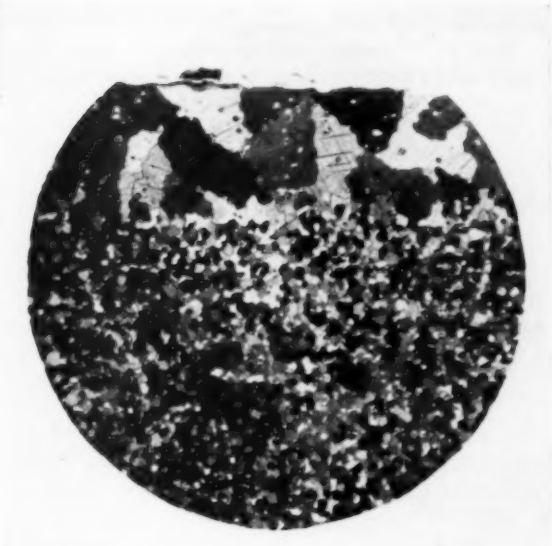


Fig. 3 — Extruded (8:1 Reduction Ratio); Annealed at 300° C.

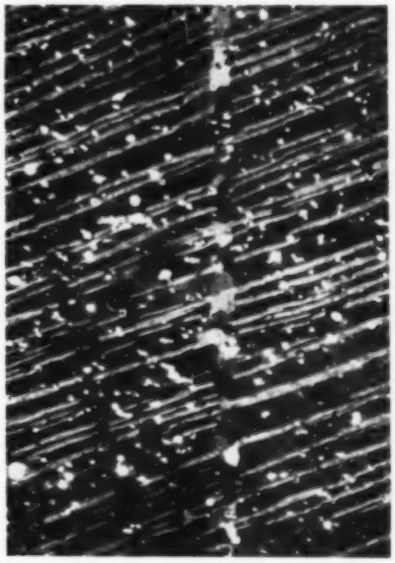


Fig. 5 — Cold Rolled 2%; Annealed, 500° C.

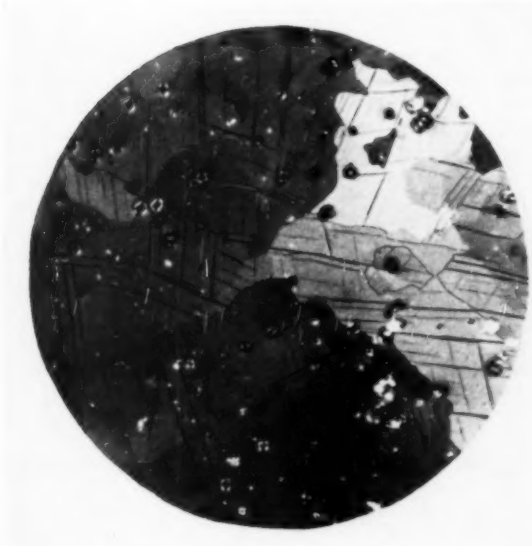


Fig. 4 — Extruded (2:1 Reduction Ratio); Annealed at 700° C.

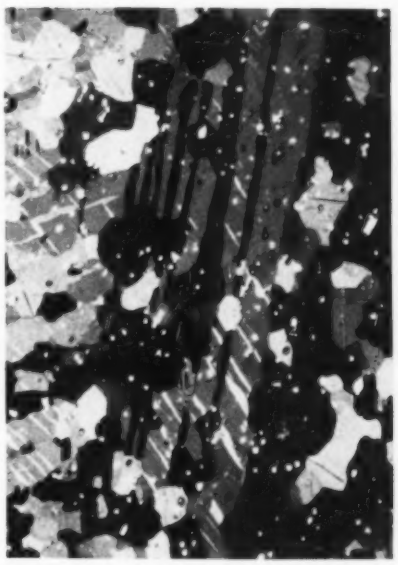
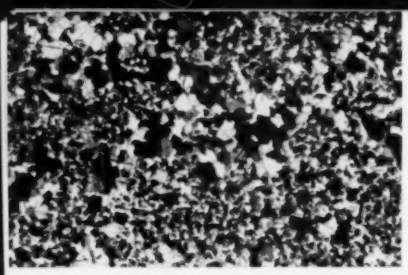
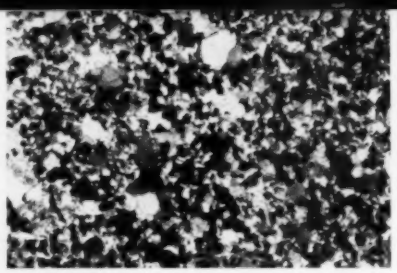


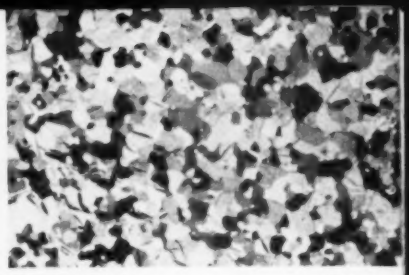
Fig.6–Rolled 10%, 500°C.; Annealed, 600°C.



Polarized Light 50 ×
Fig. 1 — "Flake" Be, As Extruded



Polarized Light 50 ×
Fig. 2 — "Flake" Be, Annealed 1000° C.



Polarized Light 50 ×
Fig. 3 — Vacuum-Cast Be, As Extruded

Metallography of Beryllium

By A. R. Kaufmann,*
P. Gordon† and D. W. Lillie‡

A SATISFACTORY etchant has not been found for revealing the microstructure of beryllium. Therefore, we have examined the unetched metal with polarized light. The specimen is cut on an abrasive wheel, polished on 320, 2/0, 3/0, and 4/0 papers, using light pressure on the final paper, and then polished with No. 1 alumina in water on a botany cloth wheel, taking 1 hr. for each ¼ sq.in. of sample area. Final polishing is for only 1 min. on a long-nap cloth wheel, using Gamal abrasive.

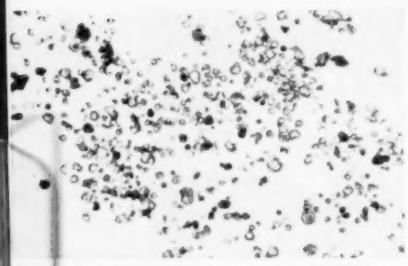
For observing inclusions in beryllium, the sample is polished through the 4/0 paper and then on cloth wheels using No. 1 alumina for about 3 min., No. 2 alumina for 2 min. and "C-RO" polishing compound for 1 min. Specimens are examined with bright field, usually after a brief etch with 2% HF in water to increase the contrast between matrix and inclusions.

Figures 1 to 4 illustrate the microstructure of vacuum-cast beryllium and of "flake" beryllium (compacted cold from paper-thin flakes produced electrolytically, and then extruded at 900° C.). Figures 5 and 6 show cast and extruded beryllium pulled in tension. The metal deforms at 200° C. by twinning and by a crystallographic process that we call "twisting" (Fig. 5). Deformation at 800° C. produces no evident twinning or twisting; the metal pulls apart at grain boundaries (Fig. 6).

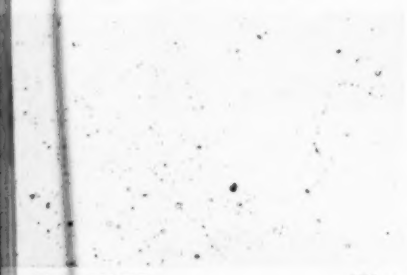
Figures 7 to 15 illustrate the effects of various alloying additions on the microstructure of beryllium.

*M.I.T. Metallurgical Project.
†Illinois Institute of Technology.
‡U. S. Atomic Energy Commission.

The authors wish to acknowledge the collaboration of H. P. Roth.



Etch: 2% HF 400 ×
Fig. 7 — Be, 1% C; Segregated Be_2C



Etch: 2% HF 100 ×
Fig. 8 — Be, 1% Fe; Fe Phase Uncertain

Etch: 2% HF 100 ×
Fig. 9 — Be, 1% N; Nitride Needles

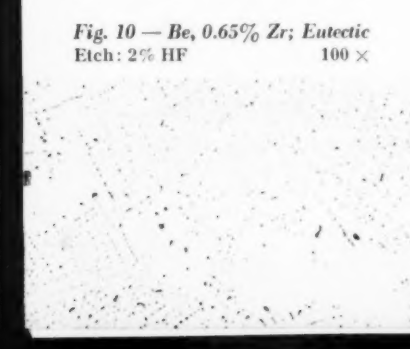


Fig. 10 — Be, 0.65% Zr; Eutectic
Etch: 2% HF 100 ×

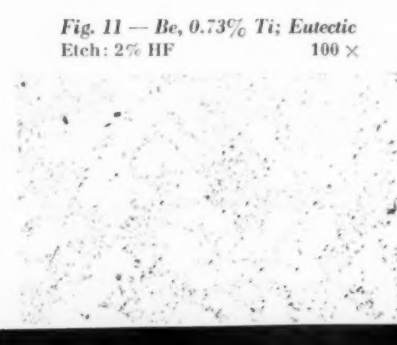


Fig. 11 — Be, 0.73% Ti; Eutectic
Etch: 2% HF 100 ×

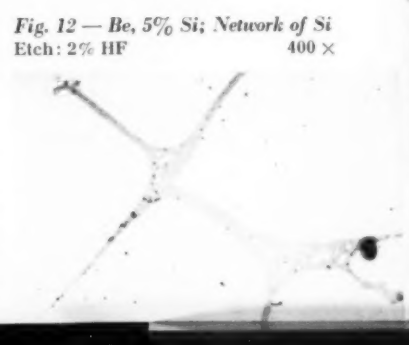
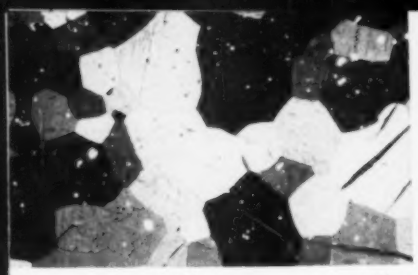


Fig. 12 — Be, 5% Si; Network of Si
Etch: 2% HF 400 ×

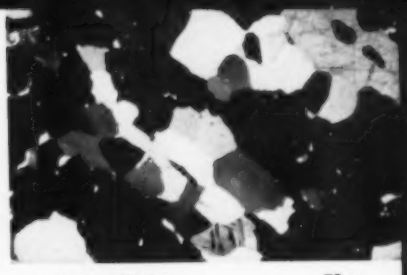


Polarized Light 50 ×

Fig. 4 — Cast Be, Annealed 1000° C.

Polarized Light 75 ×

Fig. 5 — Elongated 17.0% at 200° C.



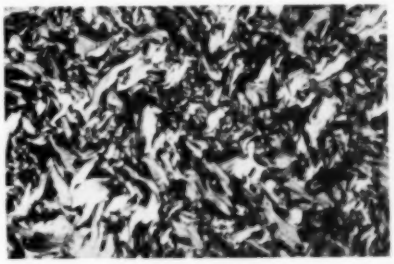
Polarized Light 75 ×

Fig. 6 — Elongated 30.9% at 800° C.

The micrographs and brief text printed here have been extracted from a paper presented at the A.S.M. Convention last month. The complete document, "The Metallurgy of Beryllium", will be published in the 1950 A.S.M. Transactions, Vol. 42. It contains extensive data on the fabrication and properties of beryllium and is a contribution from the M.I.T. Metallurgical Project, sponsored by the Manhattan Project and, since 1947, by the U. S. Atomic Energy Commission.

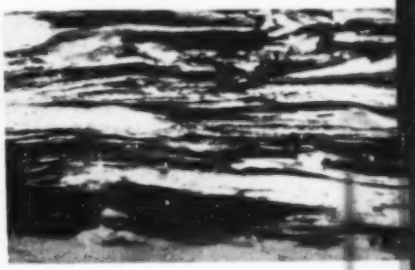
Observation of the 5% aluminum alloy with polarized light reveals that the aluminum network extends throughout the interior of individual crystals and is not concentrated at the true grain boundaries (compare Fig. 15 with Fig. 13 and 14).

Figures 16 to 21 show the effects of extrusion temperature on the microstructure of vacuum-cast beryllium. Extrusion at 500° C. is cold working (Fig. 16 and 17). At 900° C., extrusion is accompanied by partial recrystallization (Fig. 18 and 19), and for higher extrusion temperatures beryllium is completely recrystallized (Fig. 20 and 21). Twins in Fig. 20 are due to specimen preparation.



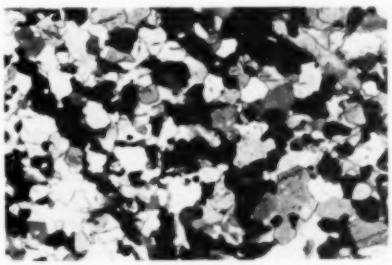
Transverse; Polarized Light 100 ×

Fig. 16 — Be Extruded at 500° C.



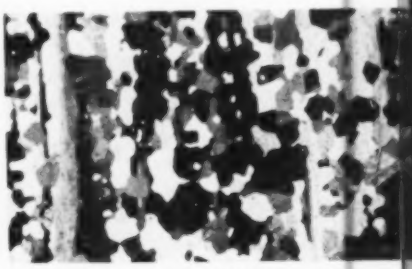
Longitudinal; Polarized Light 100 ×

Fig. 17 — Be Extruded at 500° C.



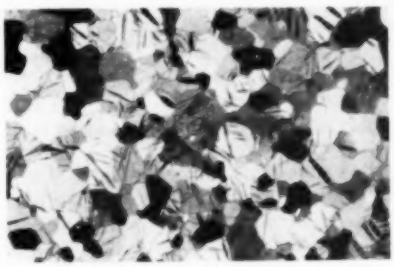
Transverse; Polarized Light 100 ×

Fig. 18 — Be Extruded at 900° C.



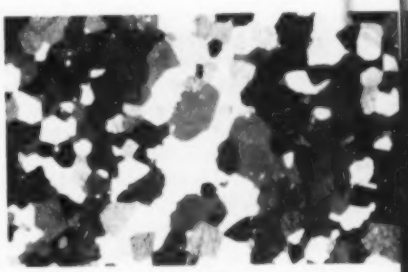
Longitudinal; Polarized Light 100 ×

Fig. 19 — Be Extruded at 900° C.



Transverse; Polarized Light 100 ×

Fig. 20 — Be Extruded at 1060° C.



Longitudinal; Polarized Light 100 ×

Fig. 21 — Be Extruded at 1060° C.

Fig. 13 — Be, 5% Al; Network of Al
Etch: 2% HF 100 ×

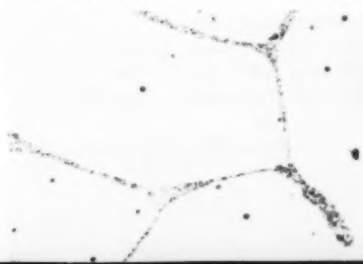


Fig. 14 — Be, 5% Al; Be-Al Eutectic
Etch: 2% HF 400 ×

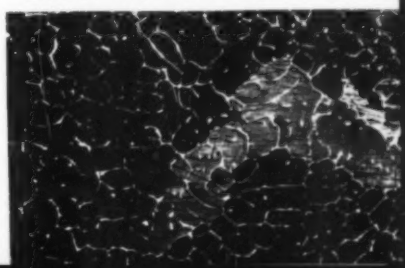
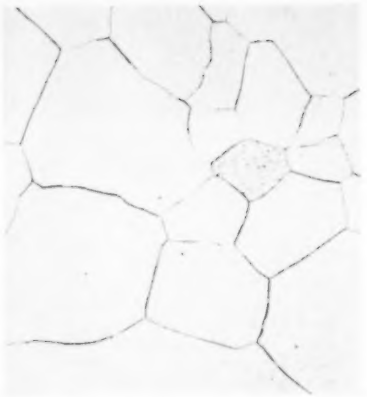


Fig. 15 — Be, 5% Al; Interior Network
Etch: 2% HF; Polarized Light 40 ×



Microstructure of Indium (99.97% In) Polished by Hand, Etched With Vilella's Reagent and Photographed at 115 ×

Metallography of

Indium and Indium-Rich Alloys

By S. C. Carapella
and E. A. Peretti
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University of Notre Dame
Notre Dame, Ind.

WITH the relatively recent availability of indium, interest has developed in the constitution of indium-rich alloys. A review of the literature reveals that many of the binary diagrams previously investigated by microscopic means were incomplete in the indium-rich composition ranges. This is partly because of the extreme softness of the pure metal, which has a Brinell number of about one, compared with three for lead and four for tin. Indium is, therefore, even more difficult to prepare for microscopic study than the two common soft metals.

In order to substantiate information obtained by X-ray diffraction and to facilitate study of phase diagrams in the indium-rich regions, a method of preparing the alloys for microscopic examination is desirable.

A technique that we have found suitable for preparing pure indium or indium-rich alloys is as follows: A flat surface is obtained with a mill file, and if the indium has not been substantially hardened by alloying, it is then polished directly on the final wheel. However, if much hardening has occurred, rough polishing is carried out on a low-speed wheel covered with billiard cloth, using for the abrasive a pasty mixture of 600-grit aluminum oxide powder, green soap and water. After the specimen has been washed thoroughly, it is then given the final polish on a low-speed wheel covered with a Selvyt cloth, using Linde B powder. The powder is heaped at the center of the wheel and mixed with green soap and water to form a paste. The polishing action is concentrated at the center of the wheel.

After final polishing, the specimen is washed, and rinsed in alcohol. It is then etched by dipping in Vilella's reagent of the following composition:

20 ml. hydrochloric acid
4 g. picric acid
400 ml. ethyl alcohol

The polishing method and reagent have been used successfully on pure indium (see micrograph at top of page), indium-cadmium and indium-zinc alloys. On indium-bismuth alloys, it has been found necessary to increase the proportions of alcohol and hydrochloric acid in the etching solution.

Metallography of Zirconium and Zirconium Alloys

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Albany, Ore.

THE CONTINUED interest and rapidly expanding production of zirconium has presented metallurgical laboratories with a new problem of devising satisfactory metallographic techniques and procedures for the study of this interesting metal and its alloys. There is marked similarity in the metallographic behavior of zirconium and titanium, and the techniques and etchants described in this paper apply almost as well to titanium as to zirconium.

Zirconium metal, although fairly hard, exhibits a marked tendency to flow during polishing. As a result, each step in grinding and polishing must be prolonged beyond the normal time required to remove the scratches from the preceding step, in order to insure the complete removal of flowed metal from the surface.

Careful preparation of specimens is essential, especially for annealed materials, because otherwise etching may exhibit false microstructures, such as twin bands that appear to cross grain boundaries without changing direction. Earlier treatments extending as far back as the sawing of the sample may influence the microstructure if the cold worked surface is not eliminated. It is sometimes necessary to remove as much as 0.030 in. of surface material in order to avoid this effect.

The routine established in this laboratory includes mounting the specimen in bakelite to facilitate the handling of sheet and odd-shaped pieces and coarse grinding on 2, 1, and 0 silicon carbide abrasive papers. Polishing is a three-stage operation: *(a)* canvas-covered lap, 280-mesh aluminum oxide, 250 r.p.m.; *(b)* felt-covered lap, 600-mesh silicon carbide, 600 r.p.m.; and *(c)* Gamal cloth lap at 600 r.p.m., the abrasive being a Linde type-B alumina suspension in distilled water containing a small amount of Aerosol wetting agent. Slowly turning laps heavily loaded with abrasives are favored; they seem to be more conducive to grinding and to produce a minimum of surface buffing or metal flow.

From a wide variety of etchants investigated, only those containing free hydrofluoric acid have been found useful. Four of the most satisfactory are listed below:

Etchant 1:	6 parts glycerine 2 parts HF 1 part HNO_3	Etching time, 3 to 5 sec.
Etchant 2:	8 parts glycerine 1 part HF ½ part HNO_3 2 to 4 parts water	Etching time, 1 to 2 sec.
Etchant 3:	20 parts HF 80 parts water 1 part conc. HNO_3	Etching time, 1 to 2 sec.
Etchant 4:	1 ml. HF 3 ml. HNO_3 3 g. $Pb(NO_3)_2$ 95 ml. water Excess metallic lead	Etching time, 3 to 5 sec.

The hydrofluoric acid referred to in these solutions is the usual 48% C.P. grade. Nitric acid is necessary to prevent the staining that usually occurs when hydrofluoric acid solutions are applied to zirconium and some zirconium alloys.

All solutions are applied with a cotton swab. The use of a swab is desirable, because a satisfactory structure often is developed only after vigorous rubbing to remove etching stains.

Etchant 1 is by far the most versatile of those listed, and is especially suitable for zirconium alloys. It develops the structures well, leaving the carbides unattacked. Good detail is produced in

Etchant 1 250 ×

Fig. 1 — Iodide Zr Melted in Graphite

Etchant 1 500 ×

Fig. 2 — Zr, 5% Si Alloy, As Cast

Etchant 1 250 ×

Fig. 3 — Zr, ½% B Alloy, As Cast

Etchant 1 250 ×

Fig. 4 — Zr, 1% Cb Alloy, As Cast

Etchant 2 250 ×

Fig. 5 — Zr, 5% Ta Alloy, As Cast

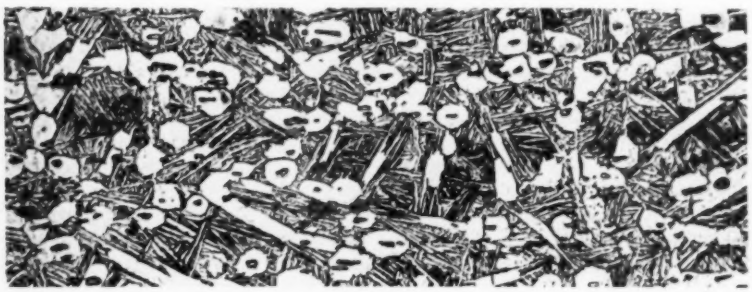
the intermediate phases. Pitting is not severe; the etching time may be prolonged several seconds without seriously affecting the surface. This solution is most effective on dry specimens; a small amount of water often produces dense stains that obscure all fine details. Figures 1 to 4 illustrate the versatility of this reagent. Figure 1 shows the fine detail in iodide zirconium melted in graphite; the carbides are well defined and remain unattacked. Figure 2 shows the two-phase structure of a cast alloy containing 5% silicon. The needlelike grains of zirconium boride and carbide dendrites shown in a zirconium matrix in Fig. 3 also are revealed with this etchant. The acicular grains in a 1% columbium alloy (Fig. 4) are sharply delineated, with good contrast and detail.

Etchant 2 is a modification of the previous reagent and contains less hydrofluoric acid and some water. It is frequently useful on more refractory alloys such as the 5% tantalum alloy shown in Fig. 5.

Figures 6 and 7 show the structure of zirconium-iron alloys cooled rapidly from elevated temperature.

Etchant 3 is even more drastic than Etchant 2. It is useful in revealing the structures in pure zirconium and some of the alloys. It reacts rapidly, and the etching time should not exceed 1 or 2 sec., since carbides are severely attacked and often completely dissolved if etching is prolonged. Figure 8 shows an area from a rod produced by the thermal decomposition of zirconium iodide. Complex structures such as occur in zirconium-manganese alloys can also be etched with this reagent.

Etchant 4 is a gentle, slow-acting reagent that produces good grain detail but stains the carbides until they are sometimes difficult to identify. It is especially useful on some

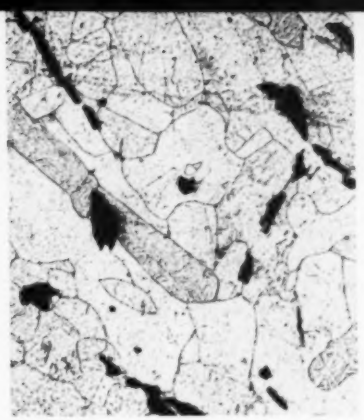


Etchant 1 250 ×

Fig. 6 — Zirconium, 0.97% Iron Alloy, Quenched From 1520° F., Alpha Plus Beta

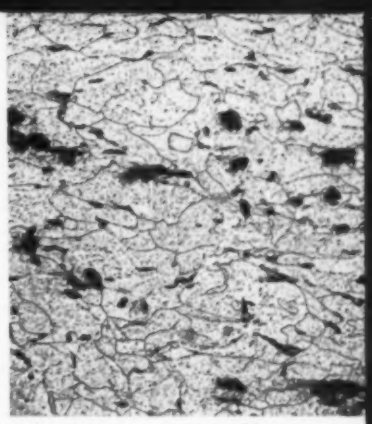
Etchant 3 250 ×

Fig. 8 — Iodide Zr, As Deposited



Etchant 3 250 ×

Fig. 9 — Bureau of Mines Zr, As Cast



Etchant 4 250 ×

Fig. 10 — Bur. Mines Zr, Rolled

of the alloys that fail to respond to any of the usual etchants. Figure 9 shows Bureau of Mines zirconium as cast, and Fig. 10, the same metal after cold rolling. The grain boundaries are sharply defined, without serious pitting, and the characteristic staining of the carbides is illustrated. The etchant also is suitable for bringing out the fine detail in pure zirconium, as illustrated by Fig. 11, which shows the intricate pattern developed in a specimen quenched from 1830° F.

Occasionally an alloy will not respond to any of the above reagents, and it becomes necessary to modify the etchant by varying the amount of free hydrofluoric acid. In general, however, one of the above solutions will fill virtually every need.

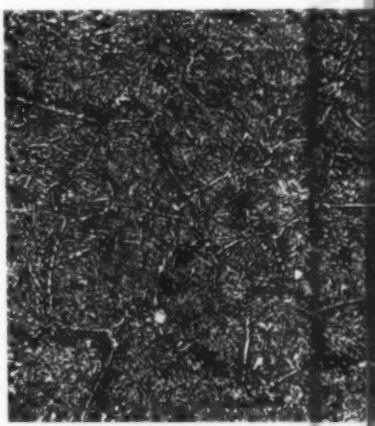
Electrolytic polishing and etching offer some interesting possibilities, although insufficient work has been done to permit definite recommendations. At present, the most satisfactory electrolytic etchants are:

Electrolytic Etchant 1:
3 parts ethyl alcohol
1 part concentrated HCl

Electrolytic Etchant 2:
450 ml. ethyl alcohol
70 ml. distilled water
25 ml. perchloric acid

The specimens are ground through 2/0 emery paper and polished 10 to 20 sec. at about 1 amp. per sq.cm. Ordinarily, no etching cycle is required to develop sharp, well-defined grain boundaries and detail which are in good agreement with those obtainable by conventional polishing and etching. Figure 12 shows the structure of as-cast Bureau of Mines zirconium developed by Electrolytic Etchant 1, at 1 amp. per sq.cm. for 20 sec.

The foregoing procedures have been found satisfactory for a large variety of zirconium and titanium metal and alloy specimens.

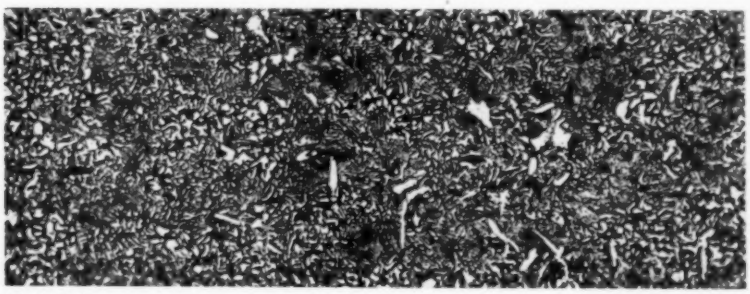


Etchant 4 250 ×

Fig. 11 — Bur. Mines Zr, Quenched

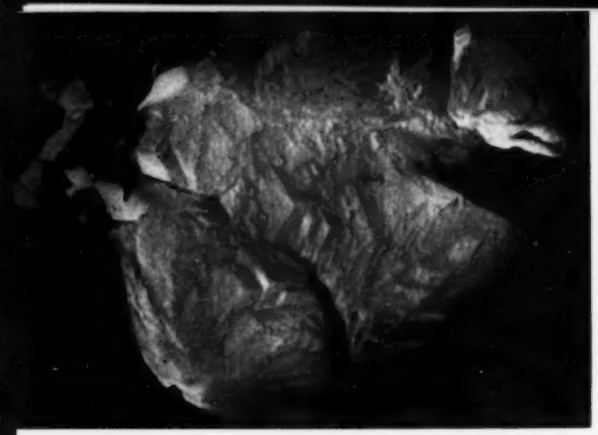
Electrolytic Etchant 1 250 ×

Fig. 12 — Bur. Mines Zr, As Cast

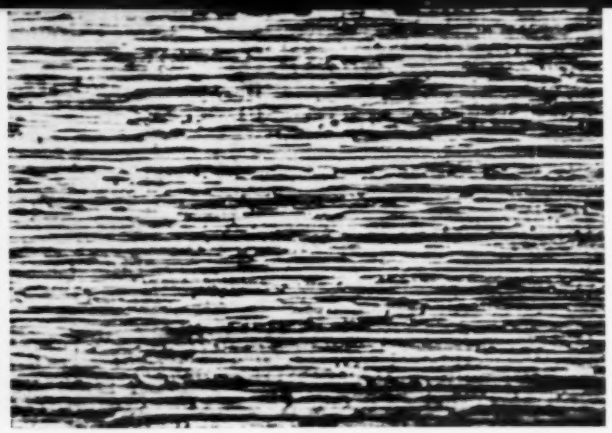


Etchant 1 250 ×

Fig. 7 — Zirconium, 2½% Iron, Quenched From 1740° F., Eutectoid Structure



Section Through a Particle of Tungsten Powder. 11,000 ×



Light Micrograph of Same Longitudinal Section Shown Below. 1150 ×

Electron Micrographs of Tungsten

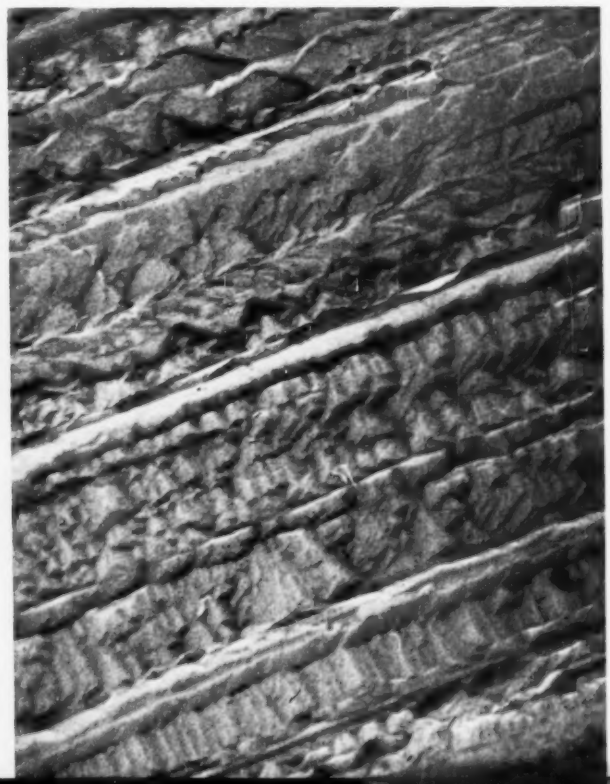
By Laurence Delisle*
Sylvania Electric Products, Inc.
Bayside, N. Y.

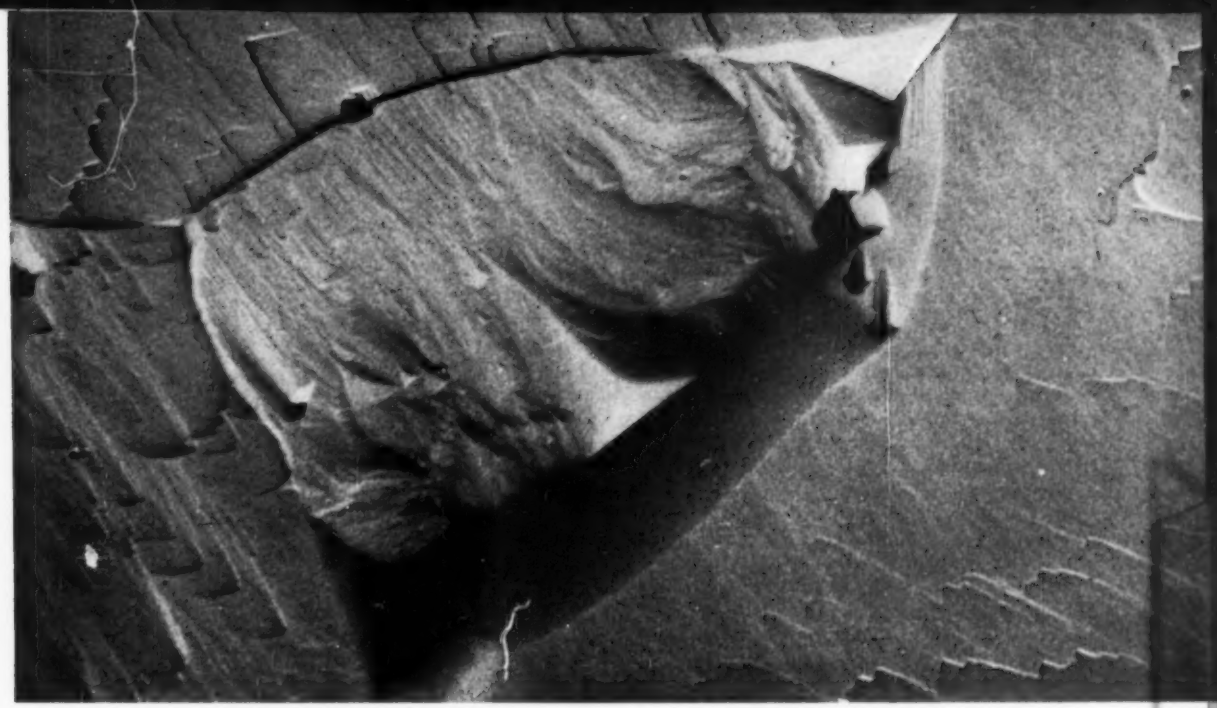
ALL the specimens were etched with an aqueous solution containing 10 g. $K_3Fe(CN)_6$, 10 g. NaOH and 100 ml. water. Parlodion replicas stripped from the surface of the samples and shadow cast with manganese were the specimens examined with the electron microscope.

*Winner of first prize, powder metallurgy division of the 1949 A.S.M. Metallographic Exhibit.

Cross Section From Annealed Wire 0.009 In. Dia. 12,000 ×

Longitudinal Section From As-Drawn Wire 0.003 In. Dia. 18,000 ×





Electron Micrographs Showing Grain Boundaries in Tungsten Rod. Magnified 18,000 Diameters

Ingot Iron

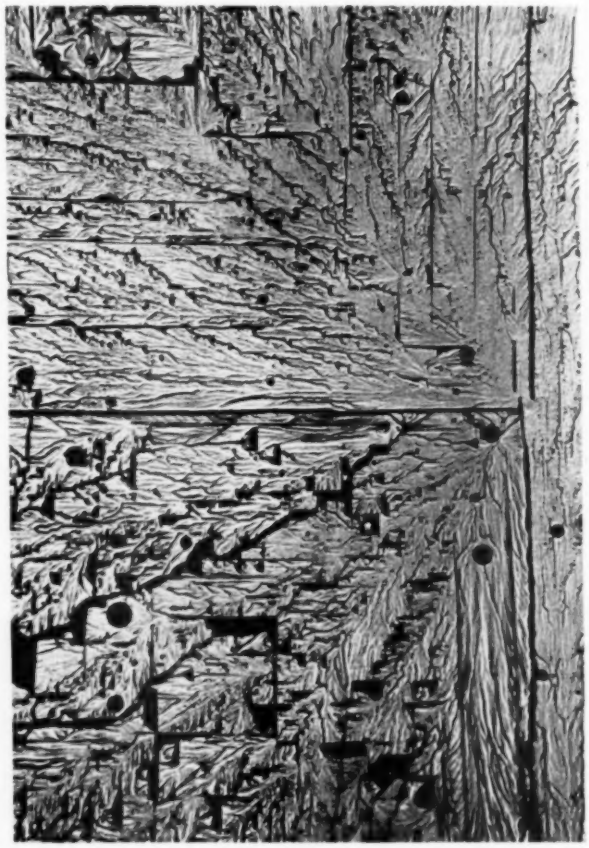
AN INDIVIDUAL grain of iron can literally be turned inside out, allowing one to study the surface of fracture from both sides, by means of "obverse and reverse" fractographs.

Our specimen, Armco ingot iron approximately ¼ x ¼ x 1 in., was cut from ¼-in. hot rolled plate. Principally to increase its grain size, the specimen was annealed 2 hr. at 1250° C. It was then embrittled by pickling for 90 min. in 10% H_2SO_4 at 90° C., lightly notched with a file, and broken by a hammer blow. Placed in the fractographic stage, the fracture was oriented, and a suitable cleavage facet was selected. It is shown in the fractograph on this page. Next, the other half of the fractured specimen was mounted in the stage, and the field was searched for the corresponding facet. Once found, this second facet was oriented exactly as its partner had been, and was projected at exactly the same magnification. Its fractograph is reproduced on the opposite page.* Thus, we have the "obverse and reverse" patterns of a single cleavage traverse through an individual grain in ingot iron, with the patterns displayed here in such a way that the two matching surfaces are "cleaved" by opening the magazine. Each view is a particularly good illustration of the cleavage pattern of hydrogen-embrittled iron. The grain boundary, of course, is well outside the field of the fractograph; the display is entirely one of intragranular architecture, modified by the hydrogen. Many crystallographic markings appear, but very few can be found at angles other than 90°.

The high pressure of hydrogen in the iron apparently blasts tiny blocks of metal from the newly formed cleavage surfaces at the instant of fracture. This gives the cleavage facet a characteristically blocklike pattern, with numerous voids of sharply rectilinear outline. We believe that these blocks and groups of blocks are the *micelles* postulated by one of us (C. A. Z.) in the paper "A New Theory for the Solid State" (to be published in the 1950 A.S.M. *Transactions*, Vol. 42), and that the hydrogen precipitates from atomic solution within the micelle into the planar boundaries between micelles.

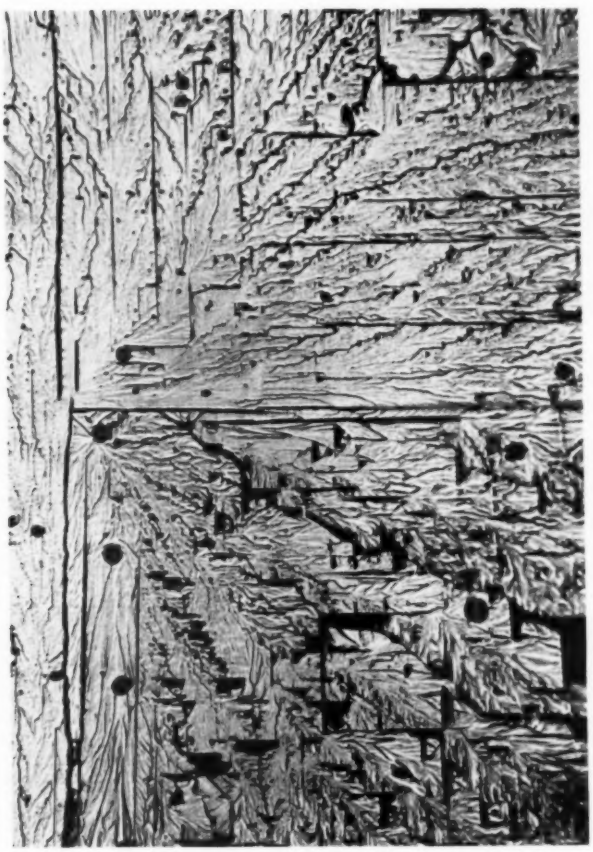
*These fractographs won a prize at the National Metallographic Exhibit in 1948.

Obverse and Reverse Fractographs of Iron
Magnified 350 ×



Inside Out

By Carl A. Zapffe
and C. O. Worden
Baltimore



When the pressure of the precipitated gas becomes great enough, the micelles are tri-axially rigidified, slip is prevented, and the condition shows as hydrogen embrittlement. Cleavage releases one component of the tri-axial compression, and the other two components literally blast micelles and micelle groups off the surface, leaving the observed voids.

By general definition, a grain is a single crystal, its boundaries delineating the form within which the solid has a single and continuous orientation. But sub-units can often be detected within a grain. These may be either *(a)* tiny fundamental crystallites variously termed "blocks", "mosaic units", and here termed "micelles", or *(b)* composites of these units, preferably termed "lineages", though sometimes called "mosaics" or "macromosaics". We prefer the term "micelle" for the first, which connotes a fundamental and persisting unit having its origin in the liquid; and "lineage", which concerns a local grouping of micelles from a single nucleation. One or more lineages may comprise a single grain.

In both fractographs, the extremely fine detail is believed to express micellar units, or multiples of them; and the larger branching structures, which appear in great abundance and detail, presumably represent the lineage pattern of crystal growth. Thus, one can observe what seems to be a frozen microscopic record of the growth process itself for this particular grain. Also note the pits and voids, some remarkably spherical.

Lastly — and the specific contribution of these double fractographs — one is enabled to follow those markings which are expressed on both sides of the cleavage traverse, *and those which are not.* One may spend an interesting hour checking details on one field against those on the other. Much of the detail is exactly symmetrical; some is slightly altered; but certain of the markings actually appear strongly on one face and not at all on the other. For example, one large pit at the lower left of the right-hand figure does not appear in the left-hand figure; and the pit immediately below the large spherical void in the left-hand figure does not appear in the facing surface.

Cathodic Vacuum Etching of Metals

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CONSIDERABLE interest has been aroused among metallographers since our first published announcement that cathodic bombardment of polished metal samples may be useful in producing excellent etched structures.[1] [References are on p. 679.] We have delayed detailed publication of our results because we do not feel that the process has been developed sufficiently to be recommended for routine use. However, a brief, general description of the method for etching metals by cathodic bombardment may be of interest. We are including here a pictorial review of our preliminary results and some comparisons of identical structures as revealed by conventional acid etching and by cathodic etching. It is hoped that others will be encouraged to investigate the possibilities of cathodic etching.

In a recent survey of the literature under the general subject of gaseous discharge, a number of publications have been found where etched metal structures were observed. Usually this etching has been viewed as a curiosity only; sometimes the effect was considered a nuisance, and efforts were made to reduce or eliminate it. Only occasionally has it been proposed that cathodic bombardment might be *useful* as a method for etching metallographic specimens.[2, 3]

Theory of Cathodic Etching of Metal — The sputtering process of depositing metals has been widely studied. Gold sputtering of wax impressions has been used in the phonograph-recording industry for years. Numerous data are therefore available concerning the many factors which control the transfer of metal in a glow discharge.[4]

A careful survey of the literature fails to reveal any general agreement on the theory of metal disintegration in a glow discharge. At least four hypotheses have been proposed to explain the removal of atoms from the surface of an ion-bombarded metal cathode. Most of these theories have been reviewed by J. J. Thomson,[5] Karl T. Compton, Irving Langmuir[6] and others.[7, 8]

Whether atoms are dislodged by vaporization, mechanical ejection due to recoil, or by some complex mechanism involving resonance need not concern us here. It is sufficient to note that the ion current created in a glow discharge has sufficient energy to cause the removal of surface atoms from the cathode. The rate of metal removal is approximately proportional to the voltage used above a minimum cathode potential, which may vary from 350 to 550 volts. This represents approximately the energy lost by internal friction as the ions pass through the surface domain of the cathode, and serves merely to heat the sample.

We have been unable to reconcile some of our observations in actual tests with any of the theories which have been proposed. For example, we find that a considerable portion of the exposure time during bombardment is required to overcome an induction period during which nothing at all appears to happen. Another curious effect is that the etch pattern may be partially removed if the process has been carried too far or if staining has developed, simply by reducing the gas pressure and the ion current.

NOTE: The authors wish to give credit to J. S. Laird and J. L. McCloud, Manufacturing Research Dept., Ford Motor Co., for visualizing the value of this work and for encouraging the development.

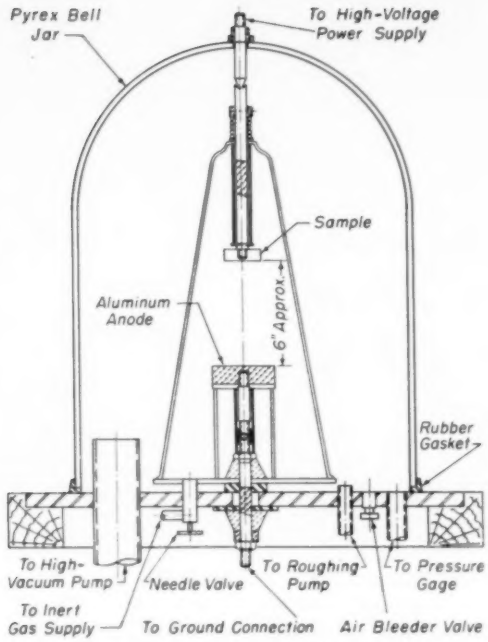


Fig. 1 — Apparatus for Cathodic Vacuum Etching

The equipment required to conduct experiments on cathodic etching of metals need not be complicated. Figure 1 shows a sketch of the glass vacuum bell jar and associated equipment used in our experiments. This equipment was available from other work and was adapted for cathodic etching by insulating all exposed metal parts with glass partitions so that all of the ion current would be confined between the anode and the test sample.

We have not observed any appreciable effect of moderate variations in the distance between anode and cathode. An aluminum anode is used solely because of its low rate of sputtering. The voltage source is not critical and apparently can be either alternating or direct current, as desired. Our early experiments were made with a 12,000-volt neon-sign transformer, which produced satisfactory results but did not allow us independent control of ion current and potential. We recently purchased a Government-surplus radar power supply (Type RA-58) which, with slight modifications, made available alternating or direct current from zero to 15,000 volts with wide variations in ion current.

Most of our cathodic etching has been done in an argon atmosphere. Reasonably good results have been obtained with air or tank nitrogen. The heaviest rare gas available would be best, as the rate of metal removal is approximately proportional to the fourth root of the atomic weight of the gas. Attempts to introduce heavy ions in an argon atmosphere, as by placing exposed mercury in the etching chamber, failed to have the desired effect. Examples of specific experimental operating conditions are given with the photographs shown.

No special precautions are necessary when photographing cathodically etched samples at high magnification on any of the commercial metallographic instruments. However, macrophotography of these samples requires a special technique, because the etched surface exhibits specular reflection with very little diffuse reflection. Chemical etching attacks a metal surface in such a way as to produce a matte surface, causing predominantly diffuse reflections. Figure 2 illustrates these effects schematically.

Figure 3 shows a sketch of camera, sample, lights and associated equipment which have been found necessary for successfully copying cathodically etched metal specimens. A thin glass plate is placed between the camera lens and the sample at an angle of 45°; this serves the same function as the glass reflector used in metallographic microscopes. A strong diverging-beam light source, such as a "baby klieg" light, three feet from the camera stand, illuminates a large frosted glass panel placed as close to the camera and sample as possible.

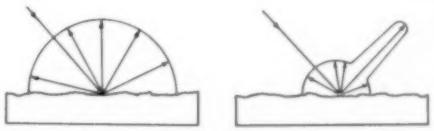
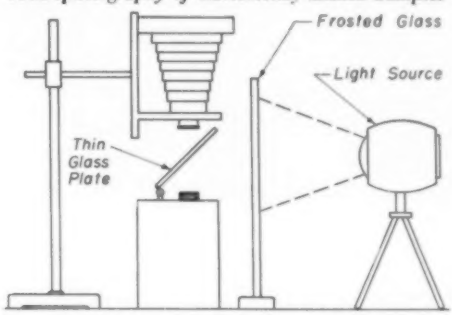


Fig. 2 — Diffuse Reflection From a Chemically Etched Surface (Left) and Specular Reflection Plus Some Diffuse Reflection From a Cathodically Etched Surface

If very large specimens are being photographed, the light angles may still not be sufficient to give full, uniform sample illumination. In such extreme cases it may be necessary to resort to ring-type illuminators or a circular fluorescent lamp placed around the camera lens.

Fig. 3 — Photographic Equipment for Low-Power Macrophotography of Cathodically Etched Samples



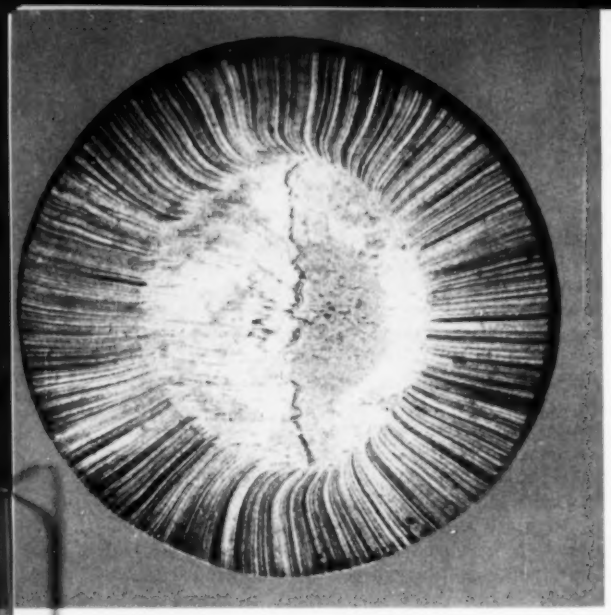


Fig. 4 — Flow Lines in Cold Headed Voltage-Regulator Contact Point. 75% silver, 23% copper, 2% nickel, 20 ×. Etching technique: argon atmosphere; 0.025-mm. pressure; 5 milliamp. d.c.; 3800 volts; etching time, 15 min.

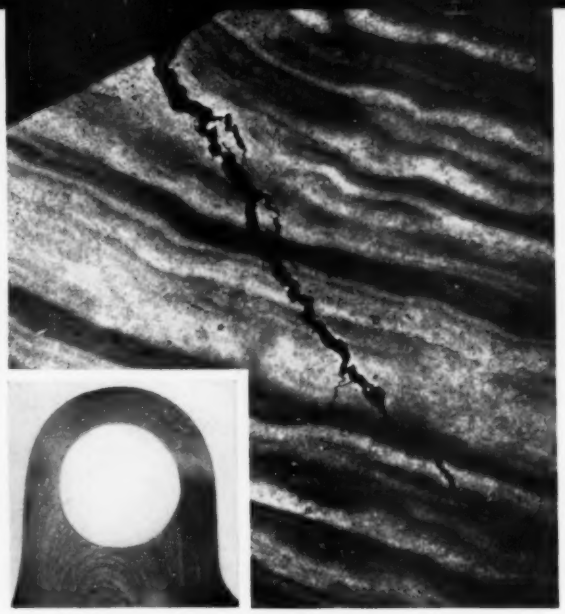


Fig. 5 — Extruded Front Wheel Spindle. Inset, full size; crack and surrounding metal magnified 100 ×. Etching technique: argon atmosphere; 0.025-mm. pressure; 20 milliamp. d.c.; 4000 volts; etching time, 2 hr.

Revealing Flow Lines

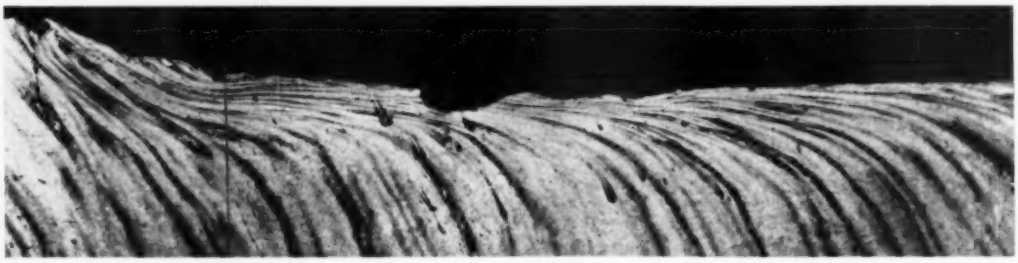
The first sample treated by cathodic bombardment was a voltage-regulator contact point (75% silver, 23% copper, 2% nickel). We were attempting to remove flowed metal from the working surface of the cold headed contact, to increase the life of the point. The flow lines were revealed by cathodic etching for the first time (Fig. 4).

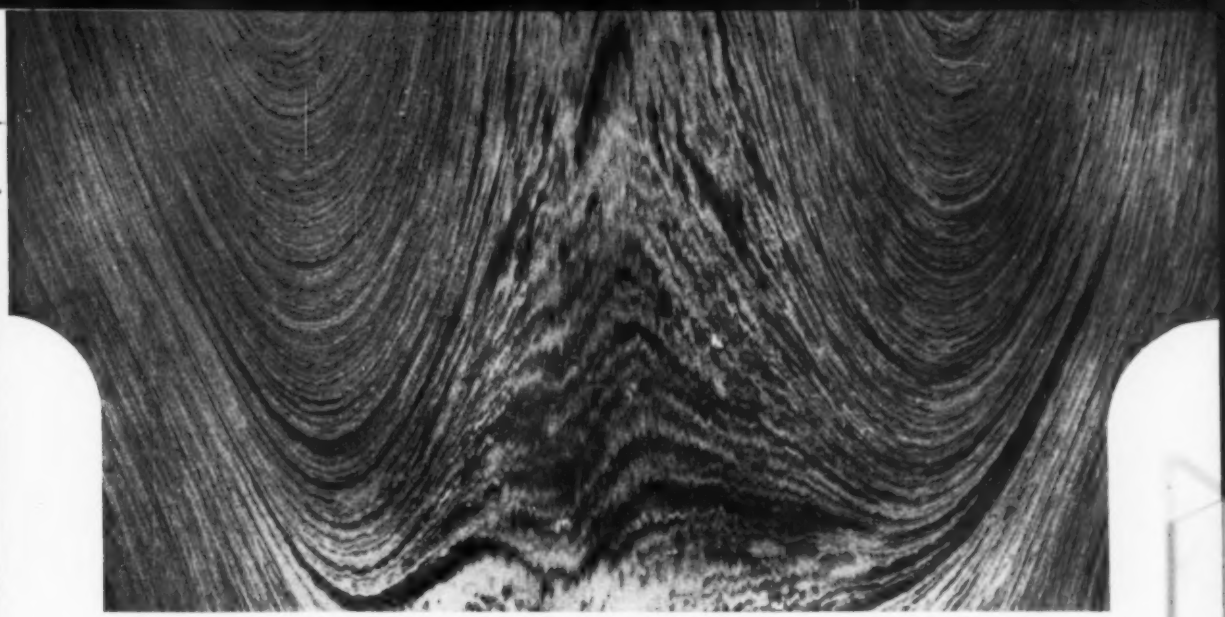
In an extruded front wheel spindle (inset of Fig. 5), microscopic examination revealed fine cracks radiating from the central hole. Acid macro-etching failed to indicate the relation of crack direction to flow lines, but cathodic etching does show the relation (see main view, Fig. 5).

On the pressure rolled fillet section of the front wheel spindle, the effective depth of the pressure rolling operation could not be detected by any chemical etching technique, either macro or micro. Cathodic etching revealed that the pressure rolling deformed the metal to a maximum depth of only 0.005 in. (Fig. 6). The ability to examine cathodically macro-etched samples at high magnification is well illustrated by this example.

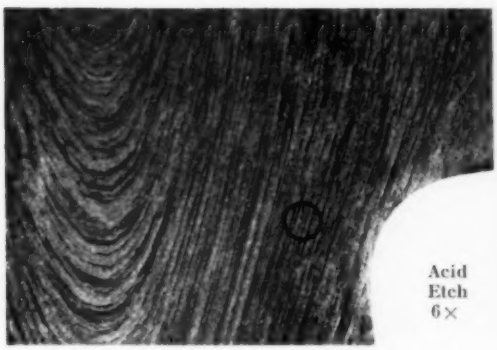
Figure 7 is a comparison of acid with cathodic etching; Fig. 8 and 9 on p. 678 show cast metal and weld metal; and Fig. 10 on p. 679 includes some results at magnifications of 500 and 1000 ×.

Fig. 6 — Pressure Rolled Fillet Section of Front Wheel Spindle. 100 ×. Etching technique: argon atmosphere; 0.025-mm. pressure; 15-milliamp. ion current using current-limiting, 12,000-volt neon-sign transformer (a.c.); exposure time, 3 hr. Etch was too heavy and was partially removed by an exposure of 45 min. at 7 milliamp. with an argon atmosphere pressure of 15 microns





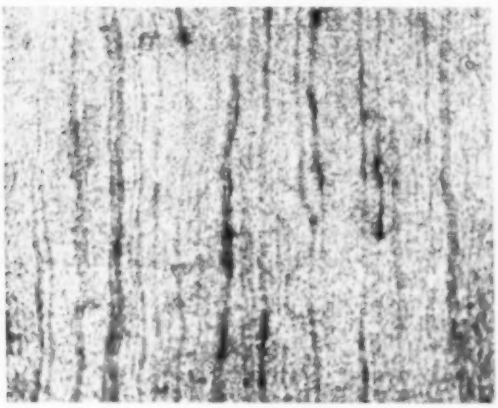
Cross Section Etched by Cathodic Discharge; 5×



Acid
Etch
6×

Cathodic
Discharge
Etch
6×

Acid Etch of Circled Area; 100×



Cathodic Etch of Circled Area; 100×

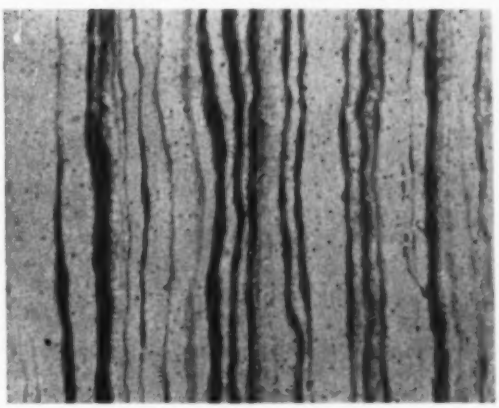
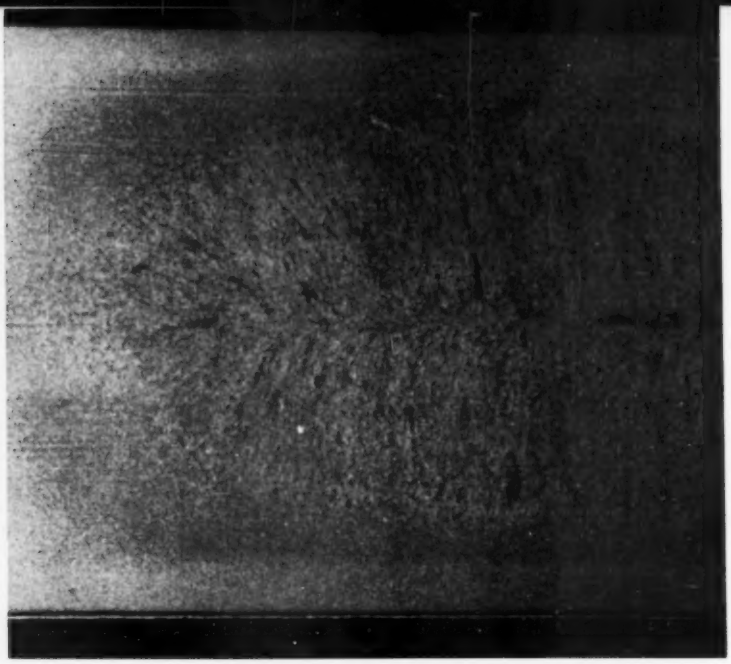


Fig. 7—Comparison of Acid Etch With Cathodic Discharge Technique for the Macro-Etching of an Extruded Spindle

Fig. 8 — Vitallium Supercharger Bucket. Magnified 5 ×. Etching technique: argon atmosphere; 0.025-mm. pressure; 10 milliamp. d.c.; 4000 volts; etching time, 2 hr. 35 min. Convex curvature of the part makes photography difficult



Above — Nital Etch. Below — Cathodic Etch. Both 16 ×

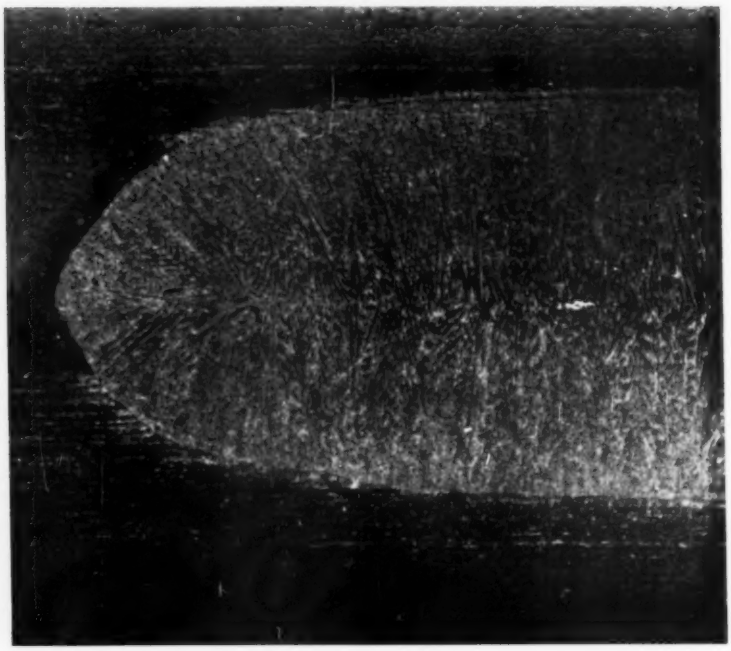
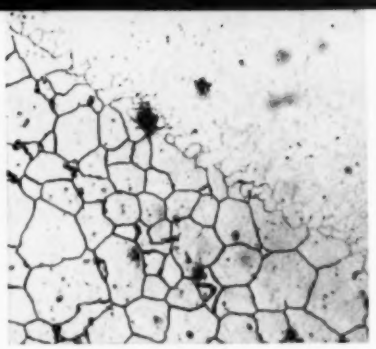


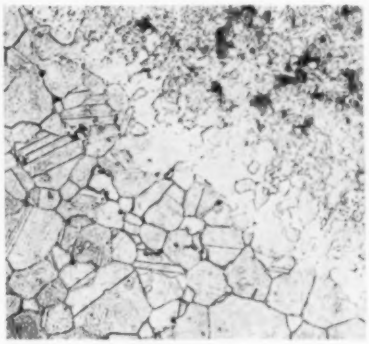
Fig. 9 — Spot Weld in Low-Carbon Hot Rolled Steel Sheet. The weld was etched in nital and, as shown in the upper view, this gave extremely low contrast. Cathodic etching, shown in the lower micrograph, gave more information than the chemical etch. Cathodic etching technique: argon atmosphere; 0.025-mm. pressure; 20 milliamp. d.c.; 4000 volts; etching time, 1 hr.

Cathodic Etch; 500×



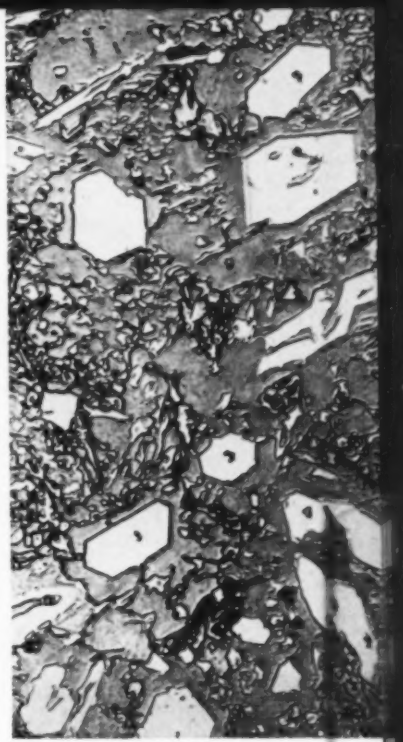
Steel Exhaust Valve

Etched With HCl + $FeCl_3$; 100×



Steel Exhaust Valve

Cathodic Etch; 100×



Hard Facing Alloy

Hard Facing Alloy

Cathodic Etch; 1000×

Fig. 10—Hard Faced Experimental Exhaust Valve, Etched Chemically and by Cathodic Vacuum Method. Exhaust valve steel contains 19% chromium, 8% nickel, 0.40% carbon; hard facing alloy, 40% cobalt, 40% nickel, 12% tungsten, 8% iron, 1% carbon. Cathodic etching technique: air atmosphere; 15-micron pressure; 10 milliamp. d.c.; 4000 volts; exposure time, 1 hr. 40 min. [The micrograph on the right won a prize at the 1949 A.S.M. Metallographic Exhibit.]

Conclusion

Cathodic vacuum etching of metal specimens has been used on a number of special problems at the Ford Motor Co. and has supplied information not obtainable by conventional methods. The results obtained, particularly on flow lines, convince us that the method can be recommended for those special problems where the extra care and time required are justified. New applications to high-magnification surveys are being made for phase and compound studies in special metallurgical problems. Highly alloyed metals, difficult to etch chemically, are especially recommended for cathodic etching. The illustrations presented here are diverse enough to indicate the excellent results which can be expected from the careful application of cathodic etching.

References on Cathodic Vacuum Etching

1. "Cathodic Vacuum Etching of Metals", by Don M. McCutcheon, *Journal of Applied Physics*, Vol. 20, April 1948, p. 414-415.

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4. "Procedures in Experimental Physics", by John Strong, Prentice-Hall, Inc., New York, 1938.

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By Anton L. Schaeffler
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Arcos Corp.
Philadelphia

Constitution Diagram for Stainless Steel Weld Metal

THE tentative constitution diagram for chromium-nickel stainless steel weld metal in the as-deposited condition has been revised to improve its accuracy in estimating the microstructure of a stainless steel weld deposit on the basis of chemical composition. This diagram has been found useful in predicting the microstructure of welds in both similar and dissimilar compositions; for example, for determining whether a deposit will contain a small percentage of ferrite, a structure known to be very resistant to weld cracking. It has likewise been helpful in predicting the electrode composition necessary for avoiding ferrite, or for avoiding martensite when maximum ductility is desired in the weld metal.

The diagram indicates the microstructure of the more common types of stainless steels, including those containing molybdenum and columbium. This is made possible by computing equivalent compositions instead of considering only chromium and nickel. Chromium and the elements silicon, molybdenum and columbium, which act like chromium from a microstructural viewpoint, are grouped to form the "chromium equivalent". Nickel and the elements carbon and manganese, which act like nickel, are grouped to form the "nickel equivalent". The "potency factors" of the elements, as compared with chromium or nickel, are given along the axes of the diagram on p. 680-B. In calculating the equivalent composition the potency factor is multiplied by the percentage of the element and added to the percentage of chromium or nickel.

The example given in conjunction with the diagram on p. 680-B illustrates how the equivalent composition is computed for a particular weld deposit of Type 318 steel. The location of this composition (point *X* on the diagram) reveals that the microstructure will be austenite plus ferrite, with between 0 and 5% ferrite. A magnetic measurement on the specimen indicated that it contained an average of 2% ferrite.

Within the range of the more common weld metal compositions, such as Types 308, 309, 309Cb, 310, 312, 316, 317 and 318 (316Cb), the diagram is reasonably accurate for estimating microstructures. Actual measurements of the percentage ferrite in austenite-plus-ferrite structures of the above grades have shown that the diagram predicts the percentage ferrite within ±4%. In the straight chromium and chromium-molybdenum stainless steels, such as Types 502, 410 and 430, the prediction of the martensite and martensite-plus-ferrite structures is qualitatively accurate. The use of the diagram for welding dissimilar metals involving austenitic weld metals and ferritic base metals gives a first approximation of the resulting microstructure when it is possible to estimate the dilution of the weld metal by the base metal.

Additional details concerning the practical application of this type of diagram to actual welding jobs may be found in previous papers.* These publications show a slightly different diagram and different potency factors. The present diagram is the result of many additional examinations of weld metals, resulting in a revision of the potency factors for silicon, columbium and molybdenum, and a slight relocation of the phase boundaries.

*"Selection of Austenitic Electrodes for Welding Dissimilar Metals", by Anton L. Schaeffler, *Welding Journal*, Vol. 26, Oct. 1947, p. 601s; and "Welding Dissimilar Metals With Stainless Electrodes", by Anton L. Schaeffler, *The Iron Age*, Vol. 162, July 1, 1948, p. 72.

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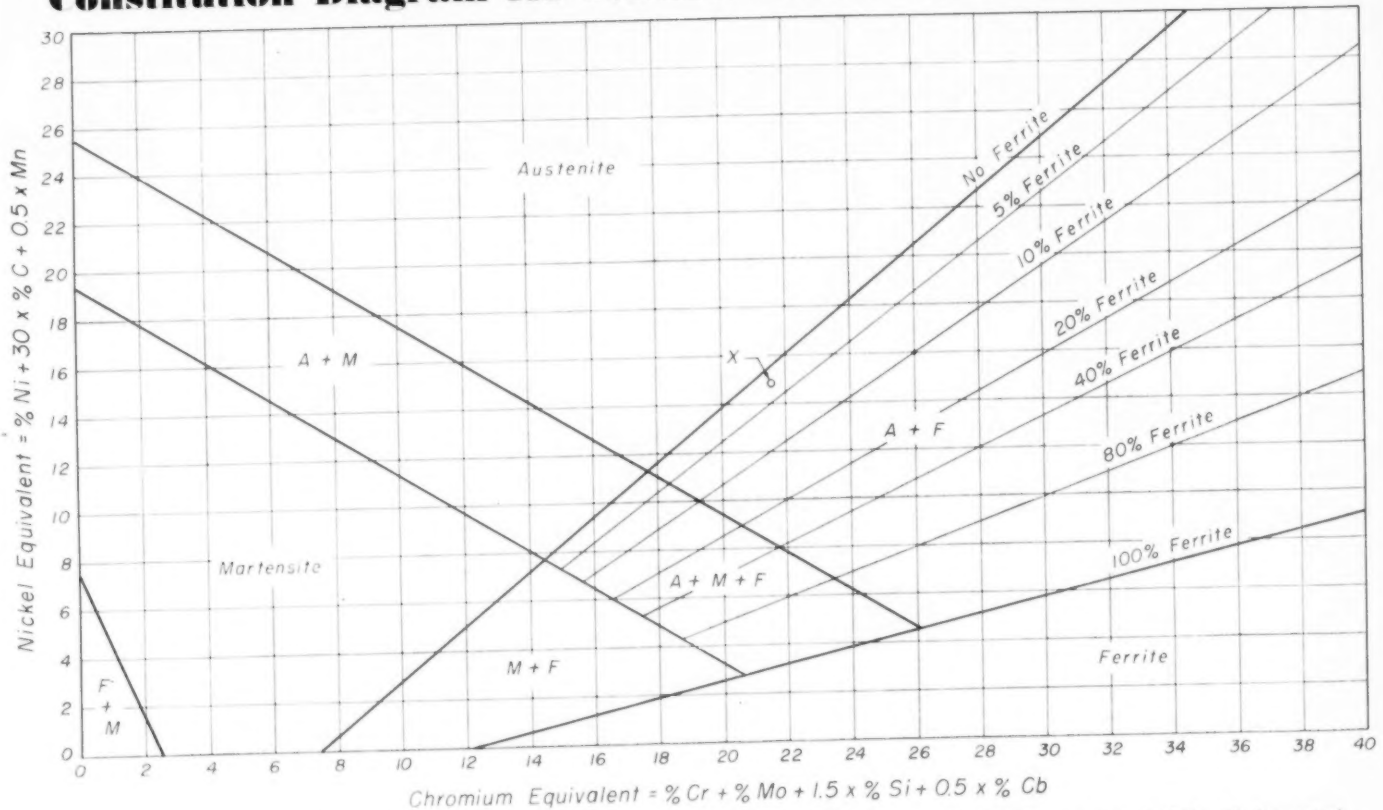
Constitution Diagram for Stainless Steel Weld Metal

By Anton L. Schaeffler


Austenite
A + M
Martensite
M + F
F + M
A + M + F
A + F
Ferrite
X
No Ferrite
5% Ferrite
10% Ferrite
20% Ferrite
40% Ferrite
80% Ferrite
100% Ferrite
Nickel Equivalent = % Ni + 30 x % C + 0.5 x Mn
Chromium Equivalent = % Cr + % Mo + 1.5 x % Si + 0.5 x % Cb
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

EXAMPLE: Point *X* on the diagram indicates the equivalent composition of a Type 318 (316Cb) weld deposit containing 0.07% carbon, 1.55% manganese, 0.57% silicon, 18.02% chromium, 11.87% nickel, 2.16% molybdenum and 0.80% columbium. Each of these percentages was multiplied by the "potency factor" indicated for the element in question along the axes of the diagram, in order to determine the chromium equivalent and the nickel equivalent. When these were plotted, as point *X*, the constitution of the weld was indicated as austenite plus from 0 to 5% ferrite; magnetic analysis of the actual sample revealed an average ferrite content of 2%.

For austenite-plus-ferrite structures, the diagram predicts the percentage ferrite within 4% for the following stainless steels: 308, 309, 309Cb, 310, 312, 316, 317 and 318 (316Cb).

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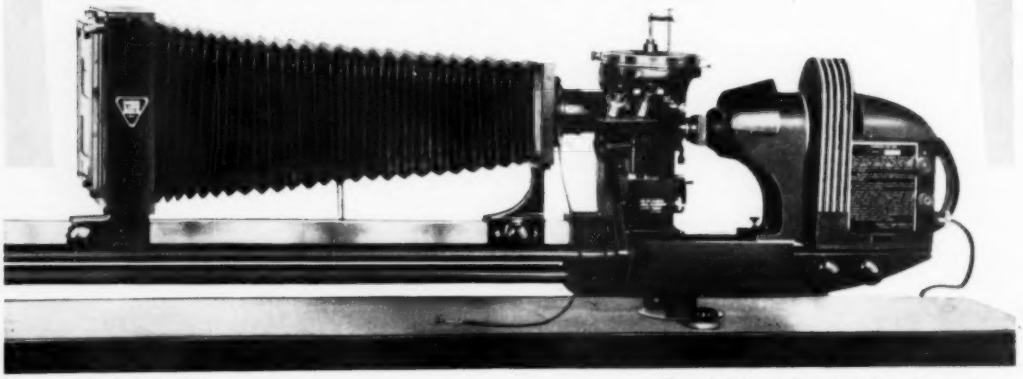
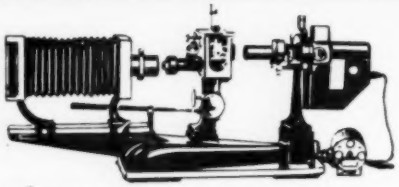


Bausch & Lomb Research Metallograph



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Flow Line Structure of Cartridge Brass

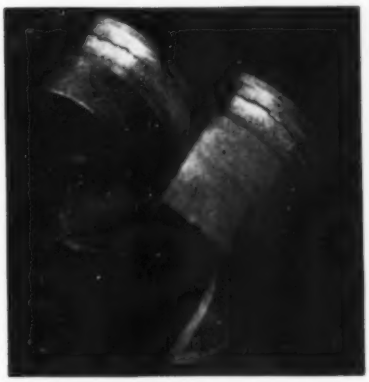


Fig. 1 — Two Head Rims That Cracked When Primers Were Being Inserted

In 1942, during the production of caliber-.50 brass cartridge cases at the Twin Cities Ordnance Plant, inspectors noticed that some cases were cracked at the head rim as they came from the machine which inserted the primer. The equipment for insertion of the primer is a machine having "fingers" that support the case, head up, by its rim. With the case thus supported, a burring punch descends to round the top edges of the primer pocket; the primer is seated by a punch; and then a three-cornered staking tool is impressed on the head, to crimp the primer in place. The pressure on the case during crimping is rather moderate, considering the strength of cartridge brass. However, it was apparently this crimping pressure that was causing the heads to crack. Figure 1 shows two examples of the defect, revealed with unusual contrast.†

In attempting to diagnose the cause of these cracks, we first tried the conventional methods of metallography. Polished and etched specimens were studied microscopically for peculiarities in grain size or shape, and for inclusions and laminations. Examination of many specimens at all magnifications failed to indicate any reason why some head rims would crack under a light pressure, whereas others sheared only under extreme stresses, as cartridge brass should. Further testing by "Baby Brinell" (15-kg. load, $\frac{1}{16}$-in. ball, using a Rockwell machine but reading the indentations like a Brinell impression) across all the areas subject to cracking revealed nothing unusual.

With all these negative results in diagnosis, and with the processing trouble changing from sporadic to "epidemic", we started research to find an etching reagent that would reveal some structural information pertinent to the solution of the problem. This research was successful; an etching procedure was discovered that would reveal the flow line structure of cartridge brass.

Etching Procedure

The procedure for etching is as follows:

1. Section, rough grind and finish the surface with No. 1, 0 and 2 0 emery paper.

2. Cover the specimen with a 15% solution of ammonium hydroxide, under a hood. (This solution contains equal volumes of water and the standard 30% ammonium hydroxide reagent.)

3. To this add 3% hydrogen peroxide solution until the total volume of the etching solution has

*Now at Wood Conversion Co., Cloquet, Minn.

†These two specimens were cleaned in a solution of potassium dichromate and sulphuric acid, in order to make them photogenic. This cleaning has greatly increased the visual contrast between crack and case. Actually, most of these defects did not show up as an evident crack, but a sharp-eyed inspector would notice a faint line just a little different from the rest of the groove, as he rolled the cartridge in his hand.

been increased by 25 to 35%. In adding the peroxide, be careful that the reaction does not become too violent.

4. Cover the dish containing specimen and solution, and let stand for about 12 hr.

5. Pour off the solution and rinse the specimen in water.

6. Brush onto the specimen a 50% solution of nitric acid. When the flow line structure becomes clearly visible to the naked eye, rinse the specimen in water and dry it in a blast of air. (Instead of brushing on the nitric acid, an excellent way to bring out the flow lines of the specimen is to moisten the grid side of a piece of Masonite or Tuff-Wood with the 50% nitric acid solution, and then to rub the face of the specimen on this board until the flow line pattern is revealed.)

Flow Line Structures

With the etching procedure just described, variations in flow line structure could be studied

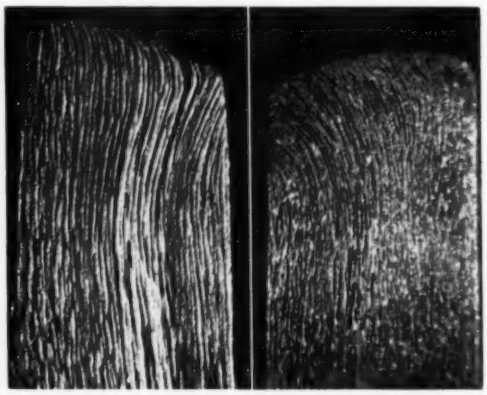


Fig. 2 — Flow Line Patterns in Side Walls From Two Cartridge Cases Blanked and Cupped on Different Types of Machines. Magnification 6 ×

for different stages in the manufacturing process and for different lots of cartridge brass. For instance, Fig. 2 shows the difference in flow line pattern of side walls from two cases that were blanked and cupped on different types of machines. Note that in the specimen on the right of Fig. 2, the flow lines have been turned into the side wall of the case, different from the left-hand view.

Figure 3* shows the flow in a "pocketed" component — that is, one into which the rough resemblance of a primer pocket has been swaged, after the piece has been through four drawing operations. At this stage the component is about 4 in. long and ⅞ in. diameter.

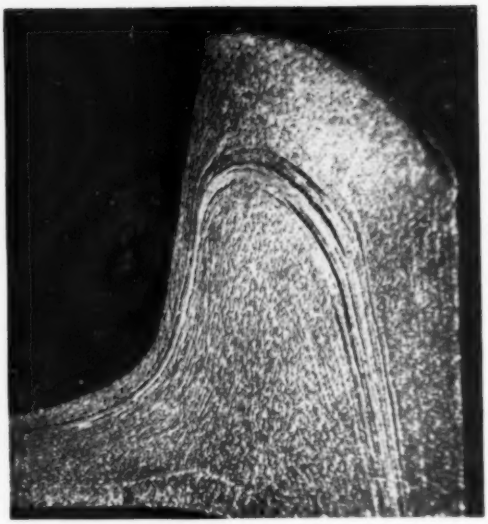
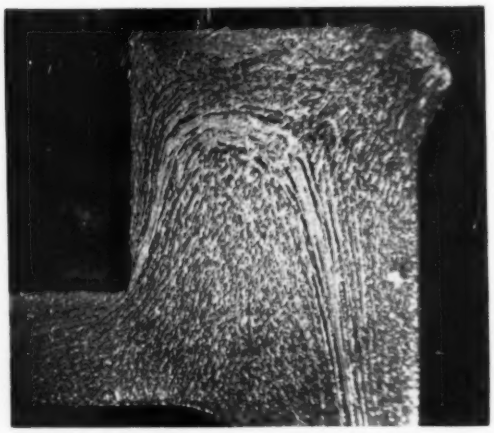


Fig. 3 — Flow After Pocketing Operation. 6.75 ×

The next manufacturing operation is heading, in which a swaging tool forms the primer pocket to proper tolerance and another face on the tool squares off the head. If all tolerances are right, only a small amount of metal is forced out, forming a slightly bulged ring around the upper side wall of the component (note upper right-hand corner of the component in Fig. 4). Figures 5

Fig. 4 — Flow After Heading Operation. 6.75 ×



*Three of the macrographs shown in this article won a prize at the 1949 ASM Metallographic Exhibit.

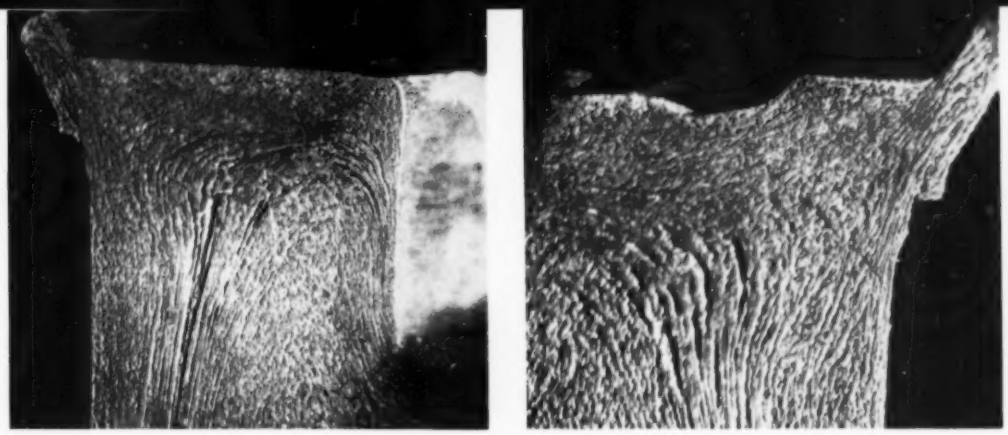


Fig. 5 and 6 — Components That Have Been Improperly Headed. Left-hand view, 6.75 ×; right-hand view, 10.5 ×

and 6 indicate what happens if uniform tolerances have not been maintained.* It might seem that the rather generous flash would not be serious because this extra metal is removed in the next operation. However, when cartridge heads are out of tolerance enough to have excessive flash, the normal, rounded flow line pattern is upset to the point of becoming rather square; the area of the square flow line corner is brought into what will be the extractor groove, and the head may crack where the flow lines intersect the surface.

Although the inspectors did not observe cracking of cases until after the primer insert operation, it became evident that the real cause of the trouble was in the previous heading. In order to determine the effect of variables in the heading operation, a large number of cases selected at random were tested in the following manner: The body of the case was hung free, mouth down, supported at the rim by parallel fingers. The assembly was set in an arbor press, and local pressure was applied to the primer pocket to simulate the primer insert and crimping operation. The test pressure was increased until the head rims showed cracks like Fig. 1, or until the rim sheared off parallel to the body. Both types of case were then sectioned and etched according to our newly devised procedure, to determine whether differences in structure could be correlated with the type of failure in the shearing test.

In cases where the rim sheared off parallel to the body, a fine undistorted flow was found, as in Fig. 7. Occasionally we observed an example like Fig. 8; not many of this type were found, but it represents a very strong head. We did not determine the cause of this type of flow line structure, which seemed to be ideal for our manufacturing operations, and we can only conjecture that it results from some rolling mill practice different from that used in producing the other material. It is well recognized that different lots of brass, though meeting the same specifications as to composition, grain size, temper and dimensions, may flow differently in a particular cold working operation. For example, Frankford Arsenal's recommendation for the first draw in making cartridge cases states that for brass manufactured by [Producer A], 4° dies shall be used, and for brass manufactured by other producers, 7° dies shall be used.

*An incidental feature to be noted in Fig. 6 is the presence of small cracks approximately at right angles to the flow lines. These small cracks, shown also in Fig. 9, developed during the prolonged etching in the ammonia solution. In effect then, the etching procedure not only reveals flow lines but also gives some incidental information about the tendency of the drawn brass to season crack in ammonia.

Fig. 7 and 8 — Head After Extractor Groove Has Been Turned in Rim. Satisfactory structure. 6.75 ×

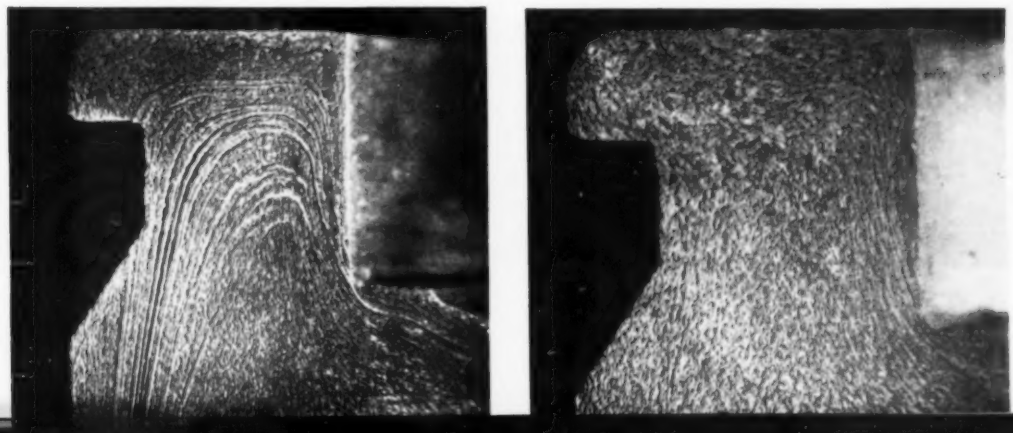


Figure 9 shows a flow line pattern more distorted than that of Fig. 7, but nevertheless one which did not weaken the head rims as tested in our simulated primer insert test. Figure 10 shows the characteristic flow found in components which would fail on the insertion and crimping of the primer. Figure 11 is a cracked head rim taken from the primer insert machine where the casualties occurred.

Effect of the Etching Procedure

The flow lines in drawn brass are not related to any structural feature that can be observed with a microscope on specimens etched in the conventional way to bring out grain boundaries.

Also, the crack in the head rim, as shown, for instance, in Fig. 11, was the same before and after etching. That is, the etching procedure does not accelerate or emphasize any cleavage along the line of flow.

The duration of the ammonia etch is not critical. To test the effect of increased time of etching, the specimen of Fig. 8 was "overetched", by leaving it in the solution for 4, 8 and 32 hr. beyond the recommended 12 hr. The additional 4 hr. caused no change, 8 hr. brought out one extremely fine line not previously visible, and 32 hr. additional etching developed a very faint pattern of flow lines similar to that shown in Fig. 7. However, this pattern was so fine as to be just barely discernible, and the conditions of lighting had to be exactly right in order to show the pattern, whereas the flow line structure of the other specimens shown in this article could be viewed readily with the naked eye and with no special lighting.

Summary

Although the etching procedure that we used enabled us to correct the manufacturing difficulty through changes in the heading operation, the fundamental differences in flow line structure remain obscure. In the drawing operations the outer part of the component is in tension and the inner part in compression. The stress condition of the central portion is more difficult to analyze. As revealed by our etching procedure, this region shows two principal types of flow line pattern, which, for want of more precise terms, we have called fine and coarse. The coarse flow, where the etchant attacks most vigorously, is the locale of structural weakness. However, with proper adjustment of the processing schedule — particularly the heading operation — to keep the coarse flow lines out of the extractor groove, any cartridge brass that meets the chemical and dimensional requirements of standard specifications can be made into cartridges successfully.

Our etching procedure was developed to aid in the solution of this one problem involving drawn cartridge brass. We have not tried the method on other copper alloys or on products made by other processes, such as drop forging, piercing, or extrusion. If other investigators can apply the etching procedure to a broader range of products, its usefulness might be extended considerably.

Fig. 9 — Head Rim Turned. Fair to good structure. 6.75 ×

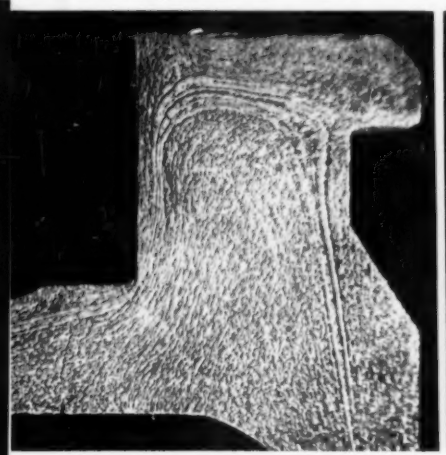


Fig. 10 — Head Rim Turned. Poor structure. 6.75 ×

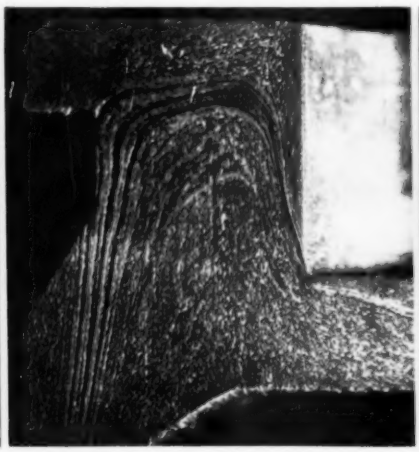
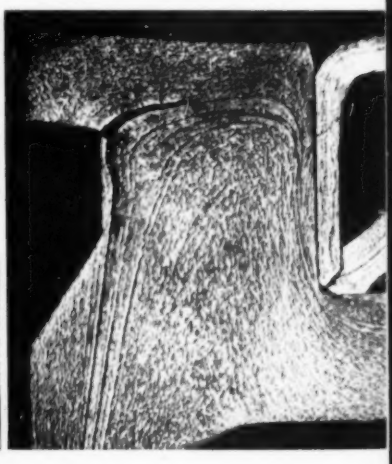


Fig. 11 — Head Rim Cracked During Primer Insert. 6.75 ×



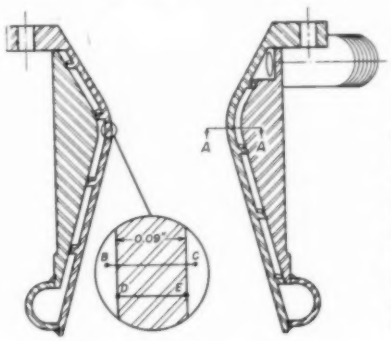
By M. C. Sanz
and H. C. Ihsen
Aerophysics Laboratory
North American Aviation, Inc.
Los Angeles

Metallographic Study of Heat Flow in Rocket Motor Walls

BECAUSE rocket motors must operate at high temperatures, their design involves consideration of the heat transfer during firing. Analysis of heat transfer depends on the accurate determination of temperature gradients, which, in the present example, have been established through a rather unusual application of metallography. The problem of heat flow involved here can be visualized from the following description of the firing of a rocket motor.

Figure 1, a cross section of a rocket motor having a thrust of 1000 lb., shows the central combustion space and the surrounding jacket through which water flows as a coolant. The circulation of water starts at room temperature before the propellants (alcohol and oxygen) are ignited. In the first fraction of a second after ignition, the temperature of the gas stream rises to about 5000° F. Heat flows through the inner wall of the steel nozzle and is taken out in the water, which increases in temperature to about 400° F. (still below the boiling point at the existing pressure of 20 atmospheres). Thus, in two or three seconds after ignition, a temperature difference of about 4600° F. is established across the distance B-C in Fig. 1, a distance only slightly greater than the wall thickness of 0.09 in. After the motor has run for 15 to 60 sec., the flow of propellant is shut off while the water is kept circulating. The cooling of the system that results is equivalent to a rapid quench of the steel wall.

Fig. 1—Cross Section of Rocket Motor. Half scale. A-A is location of Fig. 2



So much for a summary of the operation and a definition of the limiting temperatures of the two fluids. The designer must know these limits for his analysis of thrust and cooling efficiency, but to make a proper selection of material and dimensions, he is more concerned with the temperatures of the steel surfaces in contact with the gas stream and the coolant, that is, with the temperature gradient across distance D-E in Fig. 1. This gradient through the wall must be known rather accurately in order to arrive at an effective design.

On the hot side, the inner wall will be considerably cooler than the jet stream gases, and on the cold side, somewhat warmer than the cooling water. The temperature of the cold side can be measured or estimated quite easily, but the temperature of the hot side cannot. Resistance thermometers and thermocouples are difficult to install in the desired locations and such direct measurements are of doubtful accuracy because of the extremely steep temperature gradient, which is in the order of 17,000° F. per in. Other, indirect methods such as temper colors or hardness readings may be satisfactory for estimating temperatures

held constant for an extended duration, but they cannot be used reliably in connection with changes that occur during the brief operating periods of a rocket motor. Therefore, we have used a metallographic method to deduce the temperature gradient through the wall, which is made of normalized S.A.E. 4130 steel.

This metallographic method is based on the fact that part — but only part — of the rocket wall undergoes temperature changes that both austenitize and quench the steel during firing. The metallographic method is effective because the microstructure of the wall section shows a sharp line of demarcation between that part of the wall which was heated above the transformation temperature and that part which did not reach the transformation temperature while the rocket was being fired.

Procedure

The procedure for determining the temperature of the hot side of the wall is as follows:

1. A micrograph (Fig. 2) was taken of the

Fig. 2 — Microstructure at Line of Demarcation. 150×. Left-hand edge of micrograph shows surface of the wall that was in contact with the hot gases. Diamond-shaped marks are Tukon hardness indentations

cross section of the wall at a position corresponding to A-A in Fig. 1. The micrograph shows the demarcation of structure — martensite on the hot side and the original normalized structure on the coolant side.

2. Measurement from the left-hand edge of the micrograph established the position of the line of demarcation as 0.03 in. from the hot side, or 0.06 in. from the coolant side of the wall. Assuming that the line of metallographic demarcation corresponds to the transformation temperature Ac_3 (1485° F.) for S.A.E. 4130, one point on the temperature gradient has been fixed.

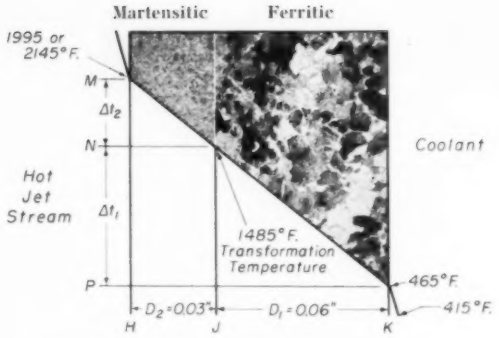


Fig. 3 — Cross Section of Rocket Motor Wall, Showing Calculated Temperatures. Micrographs are 125 ×

3. The temperature on the coolant side of the wall may be calculated from the temperature of the incoming and outgoing water, rate of water flow, Reynolds number, and other data. For a water temperature of 415° F. (at 20 atmospheres pressure) the temperature of the steel in contact with the water was calculated as 465° F.

4. Having established two temperatures and the distance between them, the temperature of the hot surface of the wall may be obtained by assuming a straight line temperature gradient, as shown in Fig. 3. The calculation is:

$$\frac{\Delta t_1}{D_1} = \frac{\Delta t_2}{D_2}$$

where Δt_1 is the temperature difference between N and P in Fig. 3.

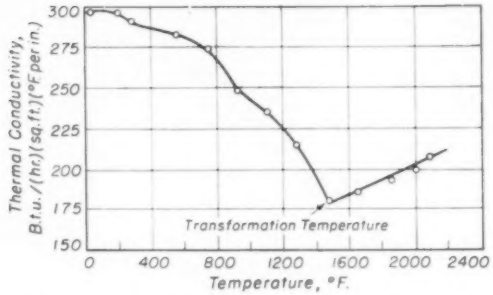


Fig. 4 — Thermal Conductivity of S.A.E. 4130 Steel

Δt_2 is the temperature difference between M and N.
D_1 is the distance between J and K.
D_2 is the distance between H and J.

$$\Delta t_2 = \frac{(0.03)(1485 - 465)}{0.06} = 510^\circ \text{ F.}$$

Thus, the temperature of the steel in contact with the hot gas is 1485 + 510 or 1995° F.

Actually, this is only a first approximation because the thermal conductivity (k) of 4130 steel varies with temperature, as shown in Fig. 4.

5. A more accurate approximation may be obtained by taking this effect into account, using two average values of k, one from 465 to 1485° F. and another from 1485 to 1995° F. Thus

$k_1 = 245$ B.t.u./(hr.)(sq.ft.)(°F. per in.) at 975° F.
$k_2 = 190$ B.t.u./(hr.)(sq.ft.)(°F. per in.) at 1740° F.

Solving for the heat flux, $q = \frac{k\Delta t}{\Delta x}$

$$q = \frac{(245)(1020)}{(0.06)} = 4.15 \times 10^6$$

$$\Delta t = \frac{(0.03)(4.15 \times 10^6)}{190} = 650^\circ \text{ F.}$$

and the temperature of the hot wall is 2145° F., instead of 1995° F., as computed in the first approximation. The temperatures through the cross section of the entire nozzle wall were calculated in this manner, as shown in Fig. 5.

Possible Errors

The inaccuracies estimated for this method are listed in Table I. We consider that the greatest single source of error results from the variation of thermal conductivity with temperature. As mentioned in a previous paragraph, this error can be minimized by using two values of k, the coefficient of thermal conductivity, in the calculations.

The Ac_3 temperature of 4130 steel is not known for high rates of heating such as obtain in the firing of a rocket motor. We have used the Ac_3 corresponding to slow rates of heating, and we believe this value is accurate within 20° F. Should it be inaccurate by as much as 100° F., the resulting error in the calculated temperature of the inner wall would still be only about 7.5%. Even an error of such magnitude would be less than that obtained by other methods which have been attempted.

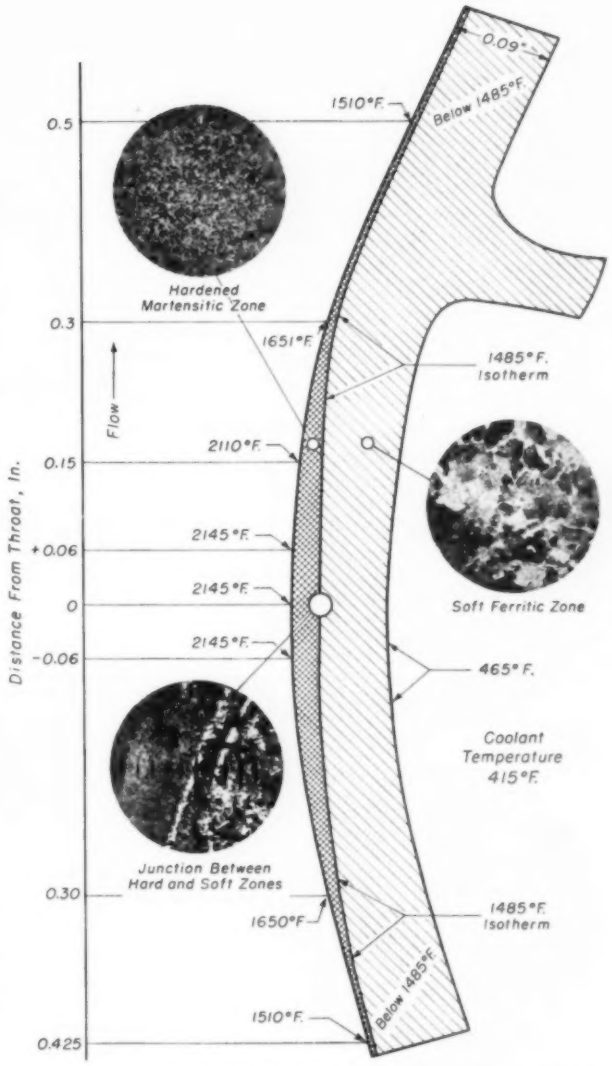
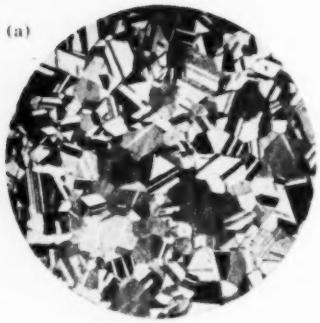
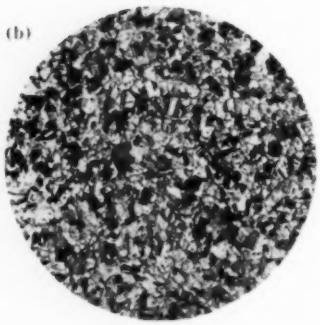


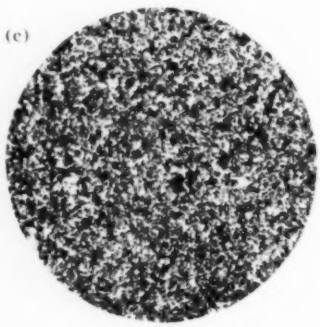
Fig. 5 — Temperature Gradient Across Wall of Rocket Motor

Table I — Summary of Possible Errors in Calculations

Variable	Probable Uncertainty	Maximum Error in Final Result
Transformation temperature, Ac_3	±20° F.	1.5%
Line of demarcation of structure	±0.001 in.	0.1%
Temperature of wall next to coolant	±20° F.	1.5%
Temperature variation of thermal conductivity, k	±10%	2%
	Maximum possible error	5%
	Maximum probable error	3%



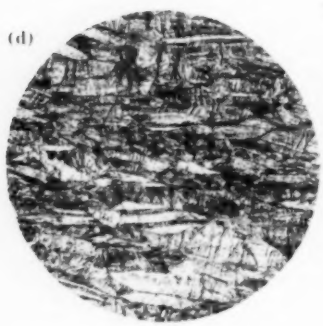


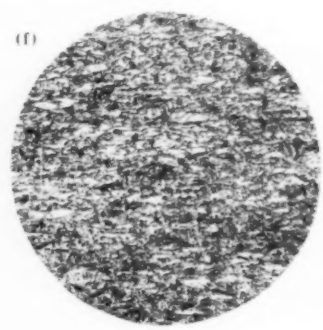


Three New Etchants for Nonferrous Metals

By Charles T. Flachbarth
Former Chief Engineer
and Chester S. Pondo
Metallurgist
Precision Tube Co.
Philadelphia

Fig. 1 — Cartridge Brass Tube Stock. Etched With Pondo's Reagent and Magnified 75×. (a) *Annealed, 0.065-mm. grain size.* (b) *Annealed, 0.025-mm. grain size.* (c) *Annealed, 0.010-mm. grain size.* (d) *Hard temper (51.1% reduction).* (e) *Spring temper (62.0% reduction).* (f) *Stress relieved 8 min. at 550° F. after cold drawing*





THE main purpose of the three etchants described here is to produce greater contrast in the microstructures of copper alloys and nickel alloys. One of these etchants, which we have called Pondo's reagent, is particularly effective on copper, alpha brasses and phosphor bronzes. The second etch, called Precision No. 1, produces good contrast on nickel specimens without the use of an electrolytic bath. It also produces a clear, flat etch with emphasis on the grain boundaries when used on Monel, but is too active for close control on alpha brass specimens. The other new etchant, Precision No. 2, is outstanding for contrast etching of high-nickel alloys, such as Monel or Ni-Span C. When diluted and used for a longer time, it loses its contrast effect on high-nickel alloys but reveals details of grain structure and boundary condition which are not otherwise discernible. Within the authors' experiences, Precision No. 1 and 2 reagents produce contrast effects superior to those obtained by electrolytic etching.

Pondo's reagent is a combination of a modified Hudson's reagent and a modified Vilella's reagent. It is prepared at room temperature as follows:

1. Dissolve 3 g. of chromic acid (CrO_3) in 15 ml. of tap water, using an open Pyrex beaker. Add 1 ml. of hydrochloric acid; then set this solution aside.
2. Pour 6 ml. of 26% ammonium hydroxide into a small graduate; then add 2 ml. of hydrogen peroxide.
3. Pour the solution prepared in step 2 into the solution previously set aside after step 1. This mixing is accompanied by a vigorous reaction, liberating heat and fumes. Do not inhale the fumes. Wash hands with soap and warm water afterward.

Figure 1 on the preceding page shows cartridge brass etched with this reagent.

For best results, Pondo's reagent should be applied to a properly polished specimen that has been rinsed in methyl alcohol and allowed to dry in air. The specimen should be swabbed briskly but lightly with the etchant for 30 to 40 sec., then washed in running tap water, dipped in methyl alcohol and allowed to dry in air. This procedure is recommended especially for specimens in the annealed condition. For cold worked specimens, better control of the etch is achieved by diluting the reagent with about 20% additional water and increasing the etching time by about 10 sec. The solution is not volatile, and can be stored in a closed bottle for several days without losing its effectiveness.

Precision No. 1—This reagent combines a modification of an etch recommended by The American Brass Co. and a modification of an etch recommended by The International Nickel Co. It is effective as a contrast etch for nickel, and as a plain etch for Monel. Preparation is as follows:

1. Pour 12 ml. of concentrated nitric acid into a graduate. Add 8 ml. of 36% acetic acid. Set this solution aside.
2. Dissolve 0.5 g. of cupric ammonium chloride crystals in 4 ml. of tap water. To this add 0.5 ml. of 26% ammonium hydroxide.
3. Pour the solution prepared in step 2 into the solution previously set aside after step 1.

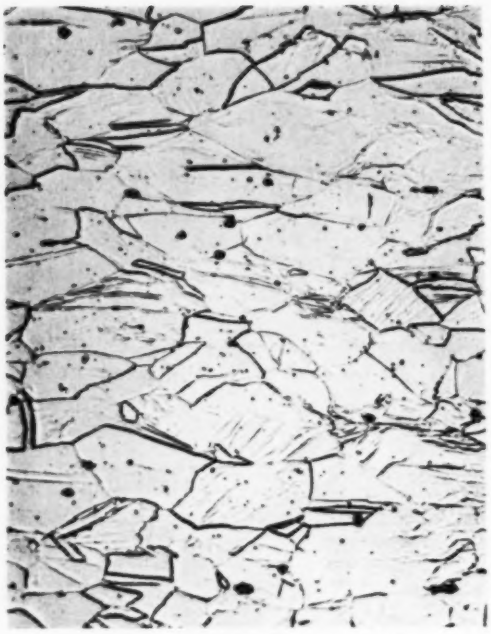
This reagent is applied in the same way as Pondo's reagent. Swabbing for 20 sec. usually is about right for annealed specimens; cold worked material is etched in a shorter time. This solution can be stored in a closed bottle for weeks, and still remain effective.

Precision No. 2—For high-nickel alloys, this reagent is the best contrast etchant that we have encountered. It is fast and stable, and is applied quickly by swabbing. Preparation is as follows:

1. Pour 3 ml. of hydrofluoric acid into a graduate. Add 6 ml. of 36% acetic acid. Next add 9 ml. of nitric acid.
2. Dissolve 1 g. of cupric ammonium chloride crystals in 8 ml. of tap water. To this add 1 ml. of 26% ammonium hydroxide.
3. Into the solution prepared in step 1, mix 9 ml. of the solution prepared in step 2.
4. Add 0.6 g. of sodium dichromate.

Good contrast is obtained on Monel and Ni-Span C by swabbing the reagent on annealed specimens for about 20 sec., on cold worked specimens for about 10 sec. As is usual with contrast etches, the specimen after etching shows light and dark areas which correspond to regions of lesser or greater amounts of cold working. Thus, some indication of stress distribution may be obtained from specimens etched with this reagent.

The use of Precision No. 2 reagent to accentuate boundaries, rather than to produce contrast, is shown in the photomicrographs of annealed, cold worked, and heat treated Ni-Span C, an age hardenable alloy of which the temperature coefficient of the elastic modulus is virtually zero from −50 to +150° F. This alloy contains 42% nickel, 5.5% chromium, 2.5% titanium, 0.06% carbon, 0.4% manganese, 0.5% silicon, 0.4% aluminum, the rest iron. The laboratory work on Ni-Span C was done at the H. A. Wilson Co., Newark, N. J., under the direction of D. Goesch, metallurgist. The micrographs on the next two pages show a series of structures of great importance in working with this alloy; metallographic inspection using the new reagents gives better metallurgical control than could otherwise be achieved.



COLD ROLLED (HIGH MAGNIFICATION)

COLD ROLLED (LOW MAGNIFICATION)

COLD ROLLED AND AGE HARDENED

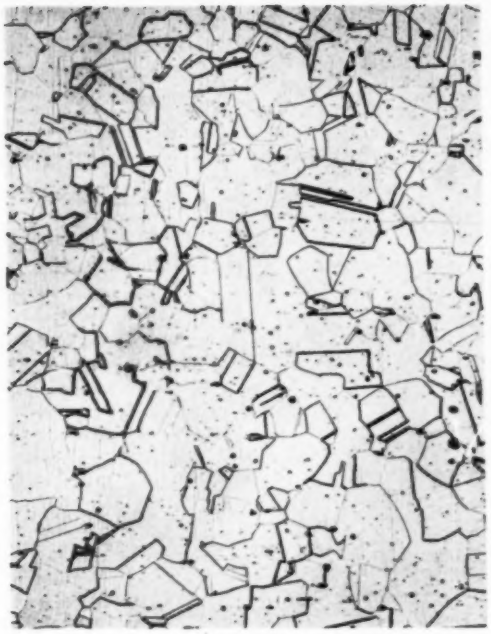
COLD ROLLED (HIGH MAGNIFICATION). After annealing, the alloy was cold rolled 50%. Note deformation markings. 500 ×

COLD ROLLED (LOW MAGNIFICATION). Same as the micrograph at left, except 200 ×. Transverse section. Rockwell C-28

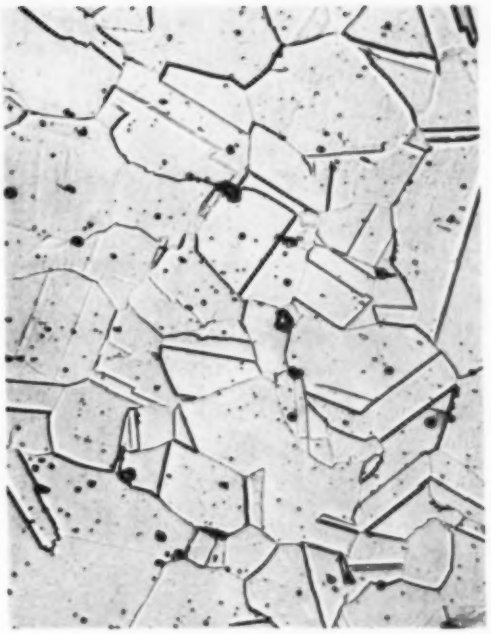
COLD ROLLED AND AGE HARDENED. After 50% cold reduction, the alloy was aged for 1 hr. at 1350° F. Transverse section. Note effects of precipitation at grain boundaries. Rockwell C-41. 500 ×

All specimens shown here have been etched with the Precision No. 2 reagent developed by Charles T. Flachbarth and Chester S. Pondo. The use of this etchant is described on the preceding page

STRUCTURE



ANNEALED



ANNEALED AND AGE HARDENED

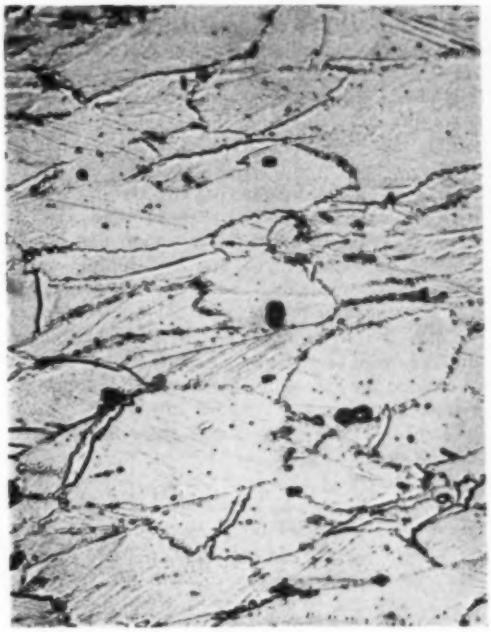
ANNEALED. Held at 1750° F. for 20 min. and then quenched in water. Note extensive twinning. Hardness, Rockwell B-68. 200 ×

ANNEALED AND AGE HARDENED. After annealing, the alloy was aged for 1 hr. at 1350° F. Hardness, Rockwell C-31. 500 ×

OVERAGED. After being annealed, the alloy was cold rolled 50% and then overaged by holding for 4 hr. at 1500° F. Longitudinal section. Note coalescence along grain boundaries. Rockwell C-28. 500 ×

Ni-Span C is a nickel-iron alloy of modulus invariant with temperature from −50 to +150° F. The composition includes 42% nickel, 5.5% chromium, 2.5% titanium and 0.06% carbon

OF NI-SPAN C



OVERAGED

Ferric Chloride Etchant for Austenite Grain Size of Low-Carbon Steel

By O. O. Miller and M. J. Day*
Research Laboratory
United States Steel Corp.
Kearny, N. J.

THERE is frequently a need to determine the size of austenite grains formed during a particular austenitizing treatment of steel with a carbon content in the range from 0.02 to 0.10%, such as that used for tin-plate or sheets. A number of methods for doing this have been employed. The carburizing[1, 2] and oxidation[3] methods alter the composition of the steel during austenitizing; this may, and often does, influence the results. The heat etching method[4, 5] has proved generally successful for these low-carbon steels but requires special equipment and hydrogen virtually free from oxygen and water vapor. Because of these considerations, a simpler method was sought and found.

The problem is: *(a)* to cool these rapidly transforming steels, especially if alloy content is low, at a rate rapid enough to produce martensite (or mostly martensite), which is needed to delineate the prior austenite grains, and *(b)* to find an etchant for revealing the austenite grains thus delineated.

Twenty low-carbon steels were investigated and the austenite grains of each one were revealed by the ferric chloride etch; eight representative steels from this group are described in Table I. The general experimental procedure for delineating austenite grains, as indicated in Table I, was: *(a)* to austenitize specimens, 0.035 to 0.13 in. thick, in dry hydrogen or vacuum (less than 0.003 atmosphere of air pressure) to minimize scaling and decarburization, and *(b)* to quench the specimens in mercury, brine or water. Scaling must be avoided because it retards the cooling rate; decarburization is detrimental because the lower the carbon content the faster the cooling required to yield martensite or a network of ferrite around martensite. Although dry hydrogen or vacuum was used in most of these experiments, other means of protecting the sample, such as copper plating or packing in cast-iron chips, have been employed successfully.

Etchants — About 200 etching solutions were investigated to determine their ability to reveal the austenite grain size of specimens of Steel 3 austenitized in vacuum for 30 min. at 2220° F., quenched in brine at 10° F. to produce martensite with traces of ferrite, and tempered for about 15 min. in the range 300 to 600° F. at 50° F. intervals. The results for etchants which reveal austenite grains are summarized in Table II. The best etches were obtained on specimens tempered in the range 300 to 400° F.; consequently, tempering of the other steels was limited to that incident to mounting in bakelite, approximately 300° F.

Results with the four best etchants found for revealing austenite grains in low-carbon martensite are illustrated in Fig. 1 by four micrographs of the *same field* of a specimen of Steel 3; the etches with ferric chloride and picric-hydrochloric acids are slightly superior to those with picral-5% nital and with 1% nital. Ferrite stands out in strong contrast to martensite when etched with ferric chloride reagent, as illustrated by the small ferritic areas marked with arrows in the upper-left micrograph of Fig. 1; conversely, it is difficult to find these ferritic areas in the same field when etched with the other reagents, as shown in the other three micrographs of Fig. 1.

The only two etchants found capable of

*M. J. Day is now with the Carnegie-Illinois Steel Corp., Pittsburgh.

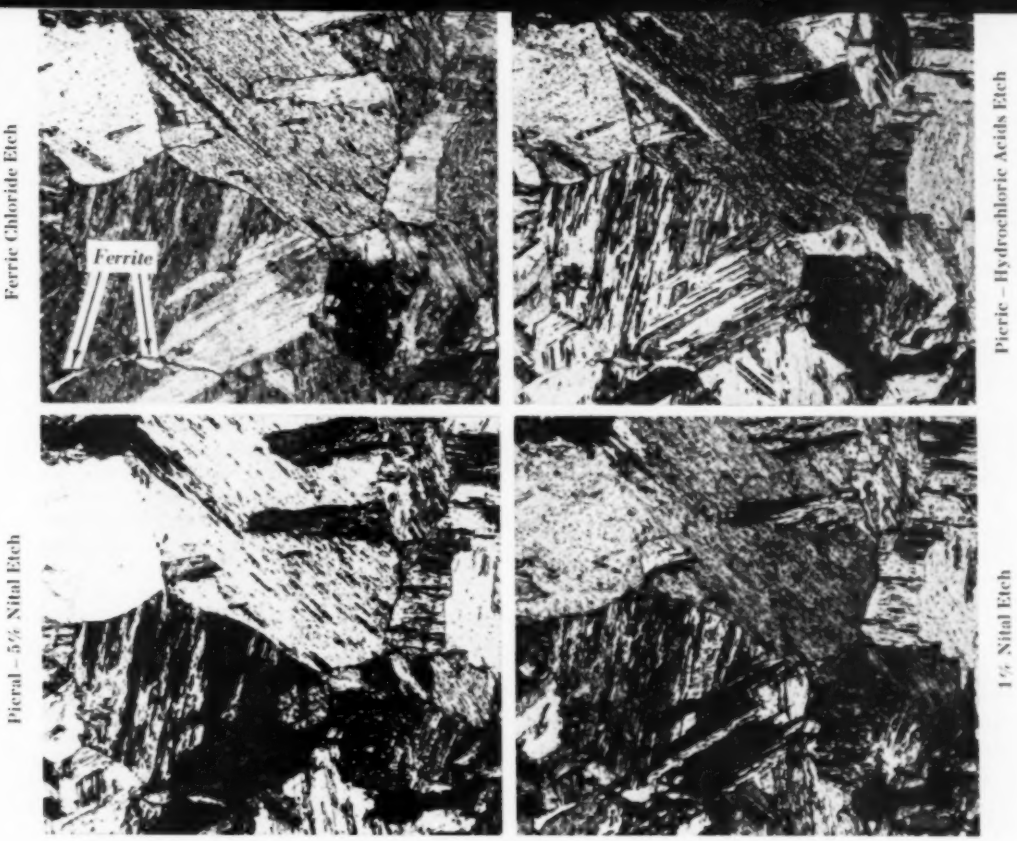
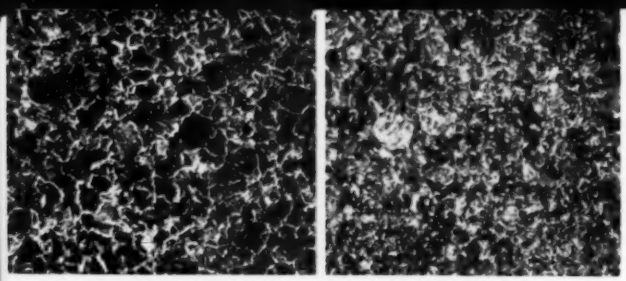


Fig. 1 — Comparison of Four Etchants for Revealing Austenite Grains in the Same Field of a Martensitic Structure Containing Only Traces of Ferrite. Steel 3 (0.05% carbon, 0.32% manganese, 0.01% silicon, 0.09% aluminum), 0.08-in. thick, austenitized in vacuum (less than 0.003 atmosphere of air) 30 min. at 2220° F. and quenched in brine at 10° F. Magnification 100 ×

Table I — Chemical Composition of Representative Low-Carbon Steels and Data Pertinent to Delineation of Their Prior Austenite Grains

Steel	Deoxidizer or Deoxidation Practice	Chemical Analysis*				Thickness of Specimen	Austenitizing Medium†	Quenching Procedure	
		C	Mn	Si	Al			Medium	Temperature
1	Aluminum	0.06	0.34	0.008	0.1	0.07 in.	Dry Hydrogen	Mercury	40 & 80° F.
2	Rimmed	0.07	0.36	0.008	0.008	0.10	Dry Hydrogen	Mercury	40 & 80
3	Aluminum	0.05	0.32	0.010	0.09	0.08	Dry Hydrogen	Mercury	40 & 80
3	Aluminum	0.05	0.32	0.010	0.09	0.08	Vacuum	Brine	10
3	Aluminum	0.05	0.32	0.010	0.09	0.08	Vacuum	Water	70
4	Aluminum	0.056	0.05	0.011	0.05	0.035	Dry Hydrogen	Mercury	70
4	Aluminum	0.056	0.05	0.011	0.05	0.035	Silver at 2000° F.	Brine	80
5	Silicon	0.08	0.30	0.10	0.004	0.10	Dry Hydrogen	Mercury	70
6	Aluminum	0.06	0.34	0.01	0.04	0.10	Dry Hydrogen	Mercury	70
7	Rimmed	0.07	0.35	0.001	0.0004	0.13	Dry Hydrogen	Mercury	70
8‡	Rimmed	0.021	0.06	0.003	—	0.02-0.06‡	Silver at 2000° F.	Brine	80

*All values are check analyses on the stock investigated, except that ladle analyses are used for manganese and silicon in Steels 1, 2, 3 and 8. †Both dry hydrogen and vacuum (less than 0.003 atmosphere of air) prevented noticeable oxidation of iron. In silver at 2000° F. the specimen acquired an oxide scale; however, it is believed that for an austenitizing time of 30 sec. or less, this scale was too thin to have a significant effect on cooling rate during quenching. Specimens immersed in silver reached their austenitizing temperature in less than 2 sec. ‡Wedge-shaped specimens were used to obtain a range of cooling rates in a single specimen. These specimens have a maximum thickness of 0.06 in. and taper down to 0.02 in. at the thin end.



Ferric Chloride Etch; Austenitized 1675° F.

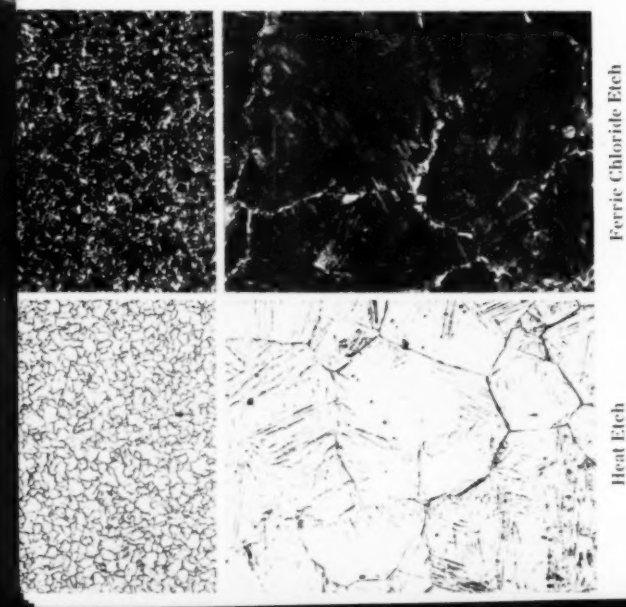
Picral Etch; Austenitized 1800° F.

Fig. 2 — Comparison of Two Etchants for Revealing Austenite Grains Delineated by Envelope of Ferrite Around Martensite. Steel 7 (0.07% carbon, 0.35% manganese, 0.001% silicon, 0.0004% aluminum), austenitized 30 min. in dry hydrogen at the temperatures indicated and quenched in mercury at 70° F. Magnification 100 ×

revealing austenite grains in low-carbon steel with a network of ferrite around martensite* are illustrated in Fig. 2. The superior delineation obtained with ferric chloride reagent is probably the result of the excellent contrast developed between ferrite and martensite, as mentioned in the preceding paragraph. Though picral was used successfully for Steel 7 containing 0.07% carbon, it is not so universally successful as ferric chloride for revealing the austenite grain size of these low-carbon steels, especially at lower carbon contents. The inferiority of picral for this use probably results from failure to develop high contrast between

*A trace of bainite, often present with the martensite, is ignored in describing the microstructure.

Fig. 3 — Comparison of Two Methods for Revealing Austenite Grains. Steel 1 (0.06% carbon, 0.34% manganese, 0.008% silicon, 0.1% aluminum), austenitized 30 min. in dry hydrogen at the temperatures indicated and quenched in mercury at 80° F. Magnification 100 ×



ferrite and martensite; at this low magnification some martensitic areas appear as white as ferrite.

Of the 200 etching solutions investigated, the ten types listed in Table II proved successful. The unsuccessful types comprise various concentrations of the following solutions: *(a)* nitric plus hydrochloric acids in ethyl alcohol, *(b)* Fry's reagent, *(c)* iodine and potassium iodide in water and ethyl alcohol, *(d)* potassium dichromate in water acidified with sulphuric or hydrochloric acids or both, *(e)* ammonium persulphate in water, *(f)* chromic acid and 1% nital in water, *(g)* hydrogen peroxide in water with and without alkali, *(h)* glycerol with nitric and hydrochloric acids, *(i)* chromic acid in water, and *(j)* oxalic acid in water. Immersion etching was employed with all of the solutions; in addition, electrolytic etching was used for chromic and oxalic acids.

Comparison of Ferric Chloride and Heat Etching Methods — Figure 3 shows the austenite grains in Steel 1 as revealed by the ferric chloride etch and by the heat etch on specimens of the same steel austenitized similarly. Since austenite grain size as revealed by these two methods is essentially identical and since Miller and Day[5] have shown that heat etching reveals the true austenite grain size of any steel, it follows that the ferric chloride method accurately reveals the austenite grain size. Furthermore, the ferrite network in these steels is, in itself, evidence of the true austenite grain size, since in hypo-eutectoid steels, in general, ferrite first forms at the austenite grain boundaries during the transformation of austenite.

Applicability of Ferric Chloride Method — Inasmuch as the method has been used successfully in this investigation to reveal the austenite grain size of about 20 carbon and low-alloy steels in the range of 0.021 to 0.10% carbon, it seems likely that it is applicable to all such steels; furthermore, the method was used successfully for steels containing 0.20% carbon and possibly would be suitable for steels containing even more carbon. The ferric chloride method was unsuccessful on four commercial irons containing about 0.015% carbon and 0.03 to 0.23% manganese; therefore, we recommend the heat-etching method when the carbon content is below 0.020%. Because accurate data on the carbon content of these low-carbon materials were necessary, the low-pressure combustion method[6] was used for analyzing the irons and for Steels 4 and 8, whereas the usual combustion method was employed for the others.

Ferric Ion Responsible for Etching — When ferric chloride is dissolved in water, ferric and chloride ions form; in addition, quite a few hydrogen ions form, since ferric chloride is the salt of a very weak base (ferric hydroxide) and a very

strong acid (hydrochloric). To determine which ion is the active one, the hydrogen ion concentration of aqueous solutions of ferric chloride was measured with the glass electrode. Solutions of hydrochloric acid with similar pH values were then tested but proved unsatisfactory for revealing austenite grains in steels which could be etched readily in ferric chloride reagent. From these observations, it appears likely that the ferric ion, and not hydrogen or chloride ions, is the effective one in etching the steel. To check this conclusion, three other ferric salts — the nitrate, sulphate and citrate — were investigated and found satisfactory for revealing austenite grains in low-carbon steels; however, all appear inferior, or at best only equal, to ferric chloride.

Recommended Procedure

The following procedure is recommended for determining the austenite grain size of low-carbon steels:

1. Use thin specimens not more than 0.04 to 0.06 in. thick; specimens less than 0.04 in. thick will be advantageous when the carbon content is less than 0.05%, especially when the alloy content is very low.

2. Austenitize the specimens under conditions which minimize scaling, carburization, or decarburization; this may be done by such methods as use of dry hydrogen, of vacuum (approximately less than 0.003 atmosphere of air), of copper-plated specimens in carburizing atmosphere, of nickel-plated specimens, or of cast-iron chips.

3. Quench the specimen in water, brine, or mercury at or below room temperature. Do not quench in oil because the cooling rate is too slow.

4. Temper for 5 or 10 min. at a temperature not in excess of 400° F.; sufficient tempering occurs while the specimen is being mounted in bakelite, and for some steels tempering probably is unnecessary.

5. Grind and polish the specimen by any good metallographic procedure, removing enough metal to get below any possible surface effect from the heat treatments. Disturbed metal can be removed by alternately polishing and etching with saturated picral or 5% ferric chloride reagent made as described in Table II. Avoid overetching with the ferric chloride reagent, as it produces pitting more readily than picral.

6. Make the final etch by immersion in 5% ferric chloride reagent. Etching time for best results is between 2 and 6 sec. for carbon steels but may be longer for some low-alloy steels.

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3. "Austenite Grain Size of Eutectoid Steel", by H. Tobin and R. L. Kenyon, *Transactions*, A.S.M., Vol. 26, 1938, p. 133-152.
4. "Heat Etching as a Means of Revealing Austenite Grain Size", by M. J. Day and J. B. Austin, *Transactions*, A.S.M., Vol. 28, 1940, p. 354-371.
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6. "Determination of Carbon in Low-Carbon Steel", by R. W. Gurry and H. Trigg, *Industrial and Engineering Chemistry, Analytical Edition*, Vol. 16, 1944, p. 248-250.

Table II — Etchants Which Reveal Prior Austenite Grains in Rapidly Cooled Low-Carbon Steel

Etchant	Etchants and Their Composition	Results*
1	*Ferric Chloride*, aqueous solution with 5% $FeCl_3$ (solutions from 1 to 10% have been used successfully)	Excellent for martensite, with and without ferrite network
2	*Picric-Hydrochloric Acids*, 1 g. picric acid and 5 ml. concentrated hydrochloric acid in 95 ml. ethyl alcohol	Excellent for martensite†
3	*Picral*, saturated solution of picric acid in ethyl alcohol	Fair for ferritic network around martensite
4	*1% Nital*, 1 ml. of concentrated nitric acid in 99 ml. ethyl alcohol	Good for martensite†
5	*Picral – 5% Nital*, one-half each, by volume, of Etchants 3 and 7	Good for martensite†
6	*2% Nital*, 2 ml. of concentrated nitric acid in 98 ml. ethyl alcohol	Not so good as Etchant 4
7	*5% Nital*, 5 ml. of concentrated nitric acid in 95 ml. ethyl alcohol	Not so good as Etchant 4
8	*Gly-Nital*, 5 ml. of concentrated nitric acid in 15 ml. of glycerol	About same as Etchant 4
9	*Picric & Hydrochloric Acids*, various amounts of each in ethyl alcohol, with and without nitric acid	No better than Etchant 2
10	*Picric & Nitric Acids*, various amounts of each in ethyl alcohol	No better than Etchant 5

*Some ferrite-carbide aggregate can be tolerated with the martensite.
†The results are poor when ferrite network is present.

By C. E. Morris
Assistant Metallurgist
Guest, Keen & Nettlefolds (Midlands) Ltd.
Birmingham, England

Electropolishing of Steel in Chrome-Acetic Acid Electrolyte

ELECTROPOLISHING of steel in mixtures of acetic acid or acetic anhydride, chromium trioxide (CrO_3), and water has already been reported by other investigators. In the following article is described a chrome-acetic acid electrolyte of very low water content that can be made up without recourse to acetic anhydride, which is a reagent inconvenient to use. What is believed to be an entirely new method of making electrical contact with the specimens is also described, as well as a somewhat unusual way of agitating the solution during electropolishing.

The composition of the electrolyte developed by the author is as follows:

Glacial acetic acid (99.5% by wt. min.)	133 ml.
Chromium trioxide, CrO_3	25 g.
Water	7 ml.

The water content is 4.7% by volume, ignoring the trace of water likely to be present in the acetic acid, and also taking no account of any possible chemical combination of the water after addition. Recognition of the solubility of chromium trioxide, not only in water but also in acetic acid, has made the above electrolyte possible without the use of acetic anhydride.

The electrolyte operates at low current densities and under optimum conditions gives to a large number of steels a mirror finish and an excellent metallographic response which, we believe, are equal to those obtainable with Jacquet's perchloric-acetic electrolyte, with the distinct advantage that the chrome-acetic solution is free from the hazards associated with Jacquet's mixture.

Preparation of the Electrolyte—The reagents are measured and weighed according to the proportions indicated, the water being added from a burette. They are then mixed in a 350-ml. conical flask provided with a cork through which passes a short piece of capillary tubing. The tubing prevents the cork from blowing off, and at the same time guards against any appreciable evaporation during subsequent heating. The flask is then placed in a water bath at 60 to 70° C. and repeatedly shaken to dissolve the chromic acid. This may take some time. Under no circumstances should anything except a water bath be used for heating, and even with a water bath, temperatures higher than 70° C. are inadvisable.

The volume of solution prepared as above is sufficient to give a depth of ½ in. in the cell, with some left over for replacing drag-out losses.

Although we have had normal results from stock bottles of electrolyte kept for several weeks, we nevertheless suspect that some slight deterioration does take place on prolonged standing, even in stoppered bottles made of nonactinic glass, and our present routine is to make up the minimum working quantity as described above and then to wait until this is fully aged before preparing more.

Needless to say, all flasks and other containers used for making up the solution must be meticulously dried.

Apparatus—The layout of the cell is shown in Fig. 1. The electrolyte is contained in a stainless steel dish which also acts as the cathode. A cooling coil of glass or stainless steel is immersed in the electrolyte, which should be just ½ in. deep. The inlet and outlet tubes of the cooling coil are coated with paraffin wax in order to minimize the possibility of condensation.

The microspecimen block, prepared as described

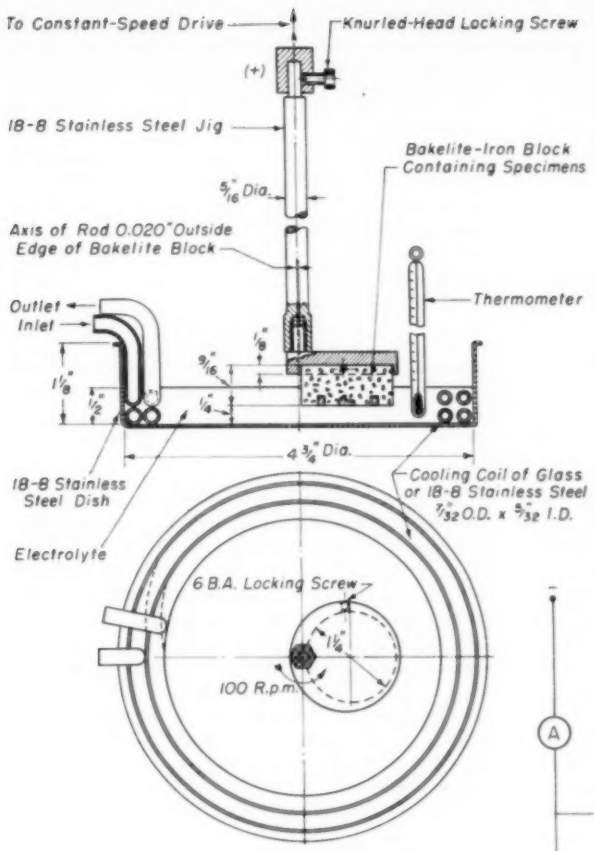


Fig. 1 — Layout of Electrolytic Polishing Cell

below, is held in a stainless steel jig, which is rotated at a constant speed of 100 ± 2 r.p.m., with the working face of the block ¼ in. away from the bottom of the dish.

The length of the jig is not vitally important. About 4 in. is convenient. The greater the length, the greater the tendency to run out of true; but a length appreciably less than 4 in. may be found somewhat inconvenient during the rinsing operations after polishing.

Because of the small working gap between specimen block and cathode, it is necessary to lower the dish somewhat before placing the jig and block in position, and again before removing the block after polishing.

A suitable source of direct current, capable of supplying up to 1.0 amp. at 20 to 25 volts, is wired up to the cell, with a voltmeter (0-25), ammeter (0-1.0), rheostat and switch as shown in Fig. 2.

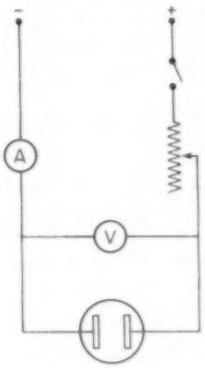


Fig. 2 — Electropolishing Circuit

Mounting of Specimens

The specimens are mounted in a bakelite-iron block 1¼ in. in diameter. The molding powder consists of an intimate mixture of three untapped volumes of "X.20" black bakelite and one untapped volume of iron dust. Both constituents are previously sieved to 60 mesh. Convenient raw materials for screening are 28-mesh black bakelite and ordinary cast-iron borings. This bakelite-iron mixture gives a block of excellent electrical conducting properties while still retaining nearly all the advantages of plain bakelite.

Prior to mounting, the specimens should be degreased, and if scaled, they should be pickled as well. If this is inadvisable, as, for example, with samples for decarburization tests, then they should be ground or filed free from scale over a reasonable area away from the face in order to make as good a contact as possible with the conducting mount.

The face of the block containing the specimens should be taken down to 3/0 emery. The back face should be given a few rubs with rough emery to remove the thin layer of plain bakelite which forms on the surface of the block, and to expose a conducting face to make good contact with the stainless steel jig.

The final thickness of the block should be kept constant to ±0.02 in. so that the working gap between specimens and cathode will not vary more than this amount, assuming the dish is moved up to the same position each time.

Temperature of Electrolyte

The operating temperature is 17 to 19° C. This is obtained by suitably controlling the flow of tap water through the cooling coil.

The amount of heat produced in the electrolyte during normal operation is such that when the water is flowing through the cooling coil fairly fast the temperature of the electrolyte rises to a fairly constant figure about 4° C. above the temper-

Table I — Electropolishing Conditions for Steel Specimens in Chrome-Acetic Acid Electrolyte

Block	Area*	Minimum Polishing Time Required†		Amp. (Approx.)	Conducting Area on Working Face of Block (Sq.In.)			Current Density‡	Remarks re Current Density Calculations
					Specimens	Iron and Graphite	Total	Amp./Sq.In.	
A	80%	6 min.		0.65	(0.8x1.227)	(0.2x1.227x0.25)	1.043	$\frac{0.65}{1.043} = 0.62$	Probably Fairly Accurate
B	2%	4 min.	At Start of Polishing	0.55	(0.02x1.227)	(0.98x1.227x0.25)	0.325	$\frac{0.55}{0.325} = 1.69$	Not Accurate
			At End of Polishing	0.47	(0.02x1.227)	Less Than Above	Less Than 0.325	$\frac{0.47}{<0.325} = >1.44$	
								Calculated§	Probably Fairly Accurate
								0.62x6/4 = 0.93	

*Area of the working face covered by specimens.

†Assuming previous polishing to 3/0 emery.

‡Conversions of current densities listed are as follows: 0.62 amp. per sq.in. = 0.096 per sq.cm., 1.69 per sq.in. = 0.262 per sq.cm., 1.44 per sq.in. = 0.224 per sq.cm., 0.93 per sq.in. = 0.144 per sq.cm.

§Calculated from polishing time required, assuming current densities calculated for block A to be accurate.

ature of the tap water. This means that if the tap water does not rise above 15° C. the temperature of the electrolyte can be kept within the correct operating limits given above. However, on certain days in summer when the water is above 15° C. it is necessary to obtain additional cooling by immersing the stainless dish in running water.

Voltage, Current, Current Density and Time

The voltage applied across the cell is 20. This is the closed circuit figure and implies that when the current is passing through the cell, the rheostat is adjusted until the voltmeter reads 20.

It has been found that this voltage gives a good polish irrespective of the area occupied by the microspecimens on the working face of the block. That is, with this setup, 20 volts gives a suitable current density no matter what this area is, for it is not the voltage but the current density that controls polishing in this electrolyte.

Although the polishing of specimens is considerably simplified by the fact that it is not necessary to make calculations and adjustments of current density, Table I is given for interest, to show how the current density may vary in practice, with a large fraction of the working face covered by specimens (block A) and with a small fraction covered (block B). The minimum polishing times quoted in this table are important.

Some explanation of the table is necessary. First, regarding the conducting area on the specimen block: The only surface with which we are concerned is the face containing the specimens. The area of the side of the block immersed in the electrolyte does not come into the calculation since that surface is nonconducting because of a thin layer of plain bakelite there. The figure of 1.227 shown in the table is the total area in square inches of the working face of the block (1¼-in. diameter).

The factor of 0.25 used in calculating the area occupied by the iron particles and the graphite is based on the fact that a blank bakelite-iron block contains approximately 25% by volume of iron and graphite. Given an intimate mixture, therefore, approximately 25% of the surface area will be occupied by iron and graphite after the thin superficial layer of plain bakelite has been removed. (The original untapped powders contain 25% by volume of iron and graphite and it has been found that this percentage is still 25 after molding.)

The initial amperage is lower for block B than for block A due to the fact that the resistance of the cell is higher for block B, on account of the smaller conducting area on the working face. The further drop in current during the polishing of block B is apparently due to the conducting area being still further reduced by: *(a)* Simple anodic dissolution of a portion of the iron particles, and *(b)* the fact that some of these may fall out of the block after being loosened by anodic attack.

The current density worked out for block A in the orthodox manner appears to be fairly accurate in view of the constant current and relatively large specimen area. Now we know that the polishing times for both blocks A and B are fairly reliable and we also know that the current density is inversely proportional to the polishing time, assuming the anode efficiency to be constant. The current density for block B has, therefore, been worked out using the polishing times for blocks A and B and the current density value for block A. Since all values used in this calculation are assumed to be reliable, the resulting current density

obtained for block B must also be fairly accurate. However, the current density worked out for block B as above does not agree with the value calculated in the orthodox manner and the latter figure cannot be trusted. One possible reason for this discrepancy may be that preferential anodic attack takes place on the iron particles when the area occupied by the bakelite-iron mixture is high compared with the specimen area, as it is for block B. A preferential attack on the iron would mean that the current density on the specimen would be lower than if the current were distributed evenly and therefore the densities calculated in the ordinary manner, and assuming an even distribution of current, yield results which are too high.

A sufficiently accurate estimation of the polishing time may be made by first estimating the approximate percentage area occupied by the specimens on the working face of the block and then interpolating between the figures given in the table.

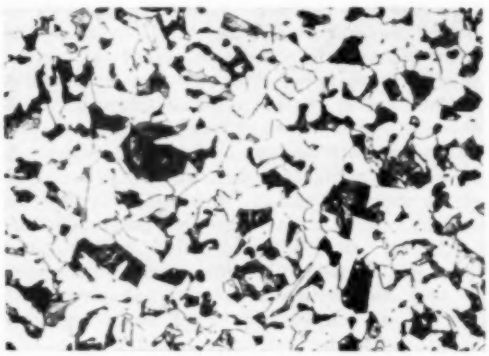
It is best to polish for the minimum time necessary to remove the emery scratches, since the longer the polishing time, the greater will be the preferential attack on the edges of the specimens and around cracks and nonmetallic inclusions.

Procedure After Polishing

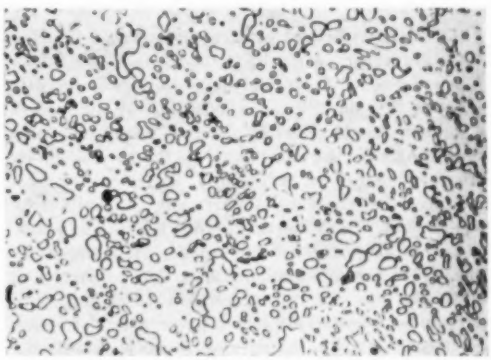
When the requisite polishing time has expired:

1. Switch off jig motor and current supply to cell simultaneously.
2. Unclamp the jig and remove it from cell.
3. Rinse specimen block for a few seconds in glacial acetic acid, holding jig by upper portion.

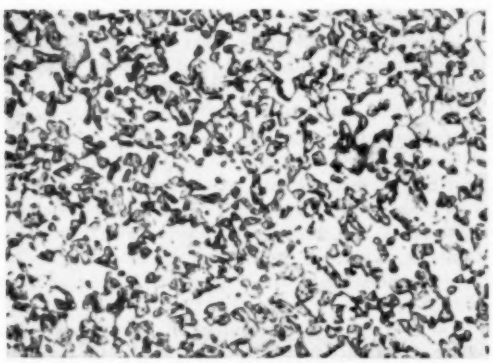
(NOTE: A delay of up to 15 sec. is permissible between steps 1 and 3, but a longer interval is inadvisable.) *(Continued on p. 710)*



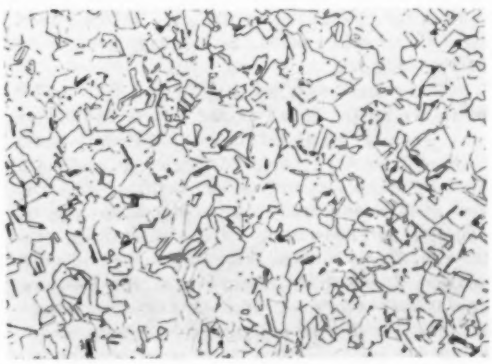
Ferrite and Pearlite in Slowly Cooled Mild Steel. Electropolished and etched in 2% nital. 200 ×



Spheroidized Carbide in Annealed 1% Carbon Steel. Electropolished and etched in 2% nital. 1000 ×



Stainless Steel Containing 16.4% Chromium, 0.09% Carbon. Quenched in oil, tempered at 480° F. Martensitic areas are gray. Electropolished and electrolytically etched for 20 min. at 0.025 amp. 200 ×



Austenitic Stainless Steel Containing 18% Chromium, 8% Nickel. Electropolished in chrome-acetic acid electrolyte and then electrolytically etched for 20 min. at 0.025 amp. 200 ×

Critical Point

By the Editor

Colorado Mines!

COLORADO School of Mines celebrated its 75th anniversary early in October, and The Editor — a gray-beard from the class of 1906 — greatly enjoyed the acute case of nostalgia it induced — a sickness made sweet by the fine young men now swarming over the campus. Not the least of many other evidences of vigorous and healthy new growth is a thriving department of metallurgy where Prof. Clark Carpenter has 65 in his senior class. Noteworthy in the mining department is the experimental mine up Clear Creek Canyon at Idaho Springs, where an abandoned drainage tunnel has been converted into a place where students get first-hand experience with hard rock mining, timbering and underground surveying. Likewise, rooms have been blasted out where manufacturers can make accurate performance tests of new designs of mining machinery. Several automatic dollies for holding heavy drills up to their work have taken much of the back-breaking labor out of a miner's life.

Some tests were in progress on drill steel — or rather on the "bits" at the cutting end. Time was when a length of hollow steel was upset, worked into star-crossed cutting edges and hardened by the blacksmith — and in those days success or failure of many a mine depended upon the competence and sobriety of the blacksmith (and the camp cook). Then came Ingersoll-Rand's drill sharpener, which is expensive except for large operations. The small mine now favors a detachable bit, like the one produced by Timken; it costs about 60¢ and is thrown away after three or four regrinds. Each bit will drill about 10 ft. in hard Gilpin County granite. Carbide bits (a single chisel-shaped wedge of cemented tungsten-tantalum carbide brazed into a slot in the drill's end) cost about $14 apiece, and so must drill at least 250 ft. to compete. Some have made 600 ft. before the outer ends of the chisel edge flaked off. Gene Bishop, Firth-Sterling's man looking after this work, said that strangely enough the relief of the edge at the central hole (through which slushing water is forced) has apparently a great deal to do with the durability of the *outer* ends of the chisel's edge! . . . Much study has been given to the drill steel and the drill itself. Is there no chance to cut drilling costs by doing something to the rock itself? Linde Air Products Co. has developed a scheme for drilling large holes largely by heat, but is there some chemical available to put into the slushing water of an ordinary air drill to *soften* the rock being drilled?

Idaho Springs, metropolis of Clear Creek County and once the mining capital of Colorado, has declined to a tourist stop on the main highway. The old stage road to Central City soon leaves steep Virginia Canyon and zig-zags up the mountain's shoulder past numberless mine dumps, past tiny Russell Gulch (now not even a signboard to show where in 1859 the first discovery of a gold lode was made in Colorado), thence over the ridge into Nevadaville and Central City and down a little canyon to Gregory Point and Blackhawk, a short mile distant — all important gold camps in Gilpin County, "the richest 120 sq.mi. in creation" — now vanished as communities. Central City alone exists as a summertime resort for folks interested in the picturesque.

The early placer workings of the early 1860's did not amount to much, since the gulches were short and steep and the creek beds are narrow — gorges rather than valleys. Fortunately, within rifle shot of the placers, up the mountain side, were outcrops of "blossom rock", the weathered

veins from which the gold came, rock so crumbly it could be loosened with a pick. Gold had to be freed from this rusty quartz, and within a year 60 stamp mills were banging away. As the workings became deeper, however, less and less of the assay values were recovered, and the new industry in Gilpin County all but expired before technology came to the rescue with a specialized stamp mill practice that splashed the freed gold against amalgamated copper plates. Several important mining groups, even districts nearby, were rich in silver rather than gold, and some entirely new concentrating machines had to be devised to replace sluices, riffles and blankets and catch the iron and copper sulphides and the silver they contained. Here the table, the classifier and the vanner (essential equipment in water concentration of fine ores everywhere) were developed. In 1868 Nathaniel P. Hill erected the first smelter in the canyon at Blackhawk for the Boston & Colorado Smelting Co. to smelt these concentrates, but his early attempts to leach the silver from the sulphide matte were failures and the matte had to be hauled 600 miles to railhead and shipped to Swansea in Wales for refining. A more famous name is Richard Pearce, who there in Blackhawk perfected the smelting of sulphide copper ore in reverberatory furnaces — the copper sulphide, in Colorado practice, being merely a regulus to catch the precious metals. Operations were transferred to Argo, near Denver, in 1878, and small trace of the old plant at Blackhawk now remains. . . . . By 1890 gold and silver production in Gilpin and adjoining Clear Creek counties reached their peak, yet to decline to nearly zero as the ore veins became thinner and deeper. Nevertheless the region yielded $150,000,000 in gold and silver in its 80-year span, nearly all from workings so small that "tiny" is the word to describe them.

For example, a series of articles by T. A. Rickard (dean of technical editors) in *Engineering & Mining Journal* for 1892 describes operations at the important California Mine where in one whole year 10,470 tons or ore (35 tons a day) were sent to the mill, assaying 1.85 oz. gold and 8.0 oz. silver and worth $27 per ton. (150 tons of hand-picked "smelting ore" carried $92 a ton in values.) He also noted that the expert millman was so essential he was the pampered pet, earning the extraordinary sum of $175 per month, more than the shift bosses in the mines! If he were writing now he would also mark the change in metal economics since 1865, when Civil War G.I.'s swarmed over the Rocky Mountains dubbing as prospectors, when gold and silver equaled money, when copper and lead were merchandise, and molybdenum and uranium merely dictionary words.

Openhearth Metallurgists Consider Oxygen and Manganese Conservation

Reported by S. W. Poole
Metallurgical Dept.
Central Alloy District
Republic Steel Corp.
Massillon, Ohio

POSSIBLY it was a sidelight on company-employee relations (which unhappily are also involved in the present disastrous strike) that those attending the September 30 meeting of the A.I.M.E.'s Openhearth Committee in Columbus, Ohio, had a good deal to say about human relations. For example, R. W. Lewry of Portsmouth Steel Co. made the point that technological improvements in the openhearth cannot be exploited to the full extent unless morale is maintained and a full sense of cooperation exists among the melters and furnace helpers. Well-executed jobs, performed by men with complete cooperation, have, as cited by the speaker, resulted in substantial increases in roof life and a more efficient use of fuel.

Training of melters and helpers should be directed toward bringing men up to date on modern improvements in openhearth operations. The idea of "trying to help the worker help himself" was stressed during the floor discussion. Class sessions with melters and helpers work out best where large groups of men are concerned; such classes at two-week intervals have been successful, in the experience of the Ford Motor Co. Education and training by such a program is the best way to overcome old fixed ideas and traditions which may or may not be correct in the light of modern technology. *(Continued on p. 722)*

Personals

Rolf Haab, formerly chief metallurgist of the Gary sheet and tin mill of the Carnegie-Illinois Steel Corp., has been appointed superintendent of tin-plate finishing and shipping.

Winchester Repeating Arms Co., Division of Olin Industries, Inc., announces that **James C. Hartley** has been appointed a staff executive. He was formerly vice-president and general manager of Barium Steel and Forge, Inc.

Ralph V. Ross has resigned as metallurgist with the Delco Appliance Div. of General Motors Corp. to accept the position of instructor in metallurgy and spectroscopy at the State University of New York, Buffalo Technical Institute.

Gerrit De Vries, formerly at the U. S. Naval Proving Ground, is now metallurgist at U. S. Naval Test Station in Pasadena, Calif.

After graduating from Colorado School of Mines, **Camillo A. Steiner** is now employed by the Denver Equipment Co., Denver, Colo.

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Timken Roller Bearing Co., Canton, Ohio, announces the appointment of **Carl E. Berndt** as manager of warehouse products. Mr. Berndt has been with Timken for the past 16 years.

New Departure Division of General Motors Corp., Bristol, Conn., announces that **Lester A. Lanning** has been appointed acting general purchasing agent. Mr. Lanning, who has been affiliated with New Departure for 30 years, has served in several capacities, most recently being assistant to the general manufacturing manager at Bristol.

Paul D. Merica, executive vice-president of the International Nickel Co. of Canada, Ltd., was elected a director of the Babcock & Wilcox Co.

Whitehead Metal Products Co., Inc., announces that **Clayton D. Grover**, vice-president, has been elected a director of the company. Mr. Grover joined the International Nickel Co. in 1925 and was transferred to Whitehead Metal Products Co. in 1927. He was in technical sales in Boston, Buffalo and New York before being elected vice-president.

Geo. D. Prest, Jr., has been transferred from Chicago sales engineering department of Lindberg Engineering Co. to the new office of the company in Los Angeles.

R. F. Gill has been transferred from research assistant at the Knolls Atomic Power Laboratory of General Electric Co., to metallurgist at the works laboratory, Schenectady, N. Y.

International Derrick & Equipment Co. announces the appointment of **Kenneth L. Mills** as product manager of oil field sales with the Columbus, Ohio, division. Mr. Mills was formerly chief mechanical engineer with Emsco Derrick & Equipment Co., Houston, Texas.

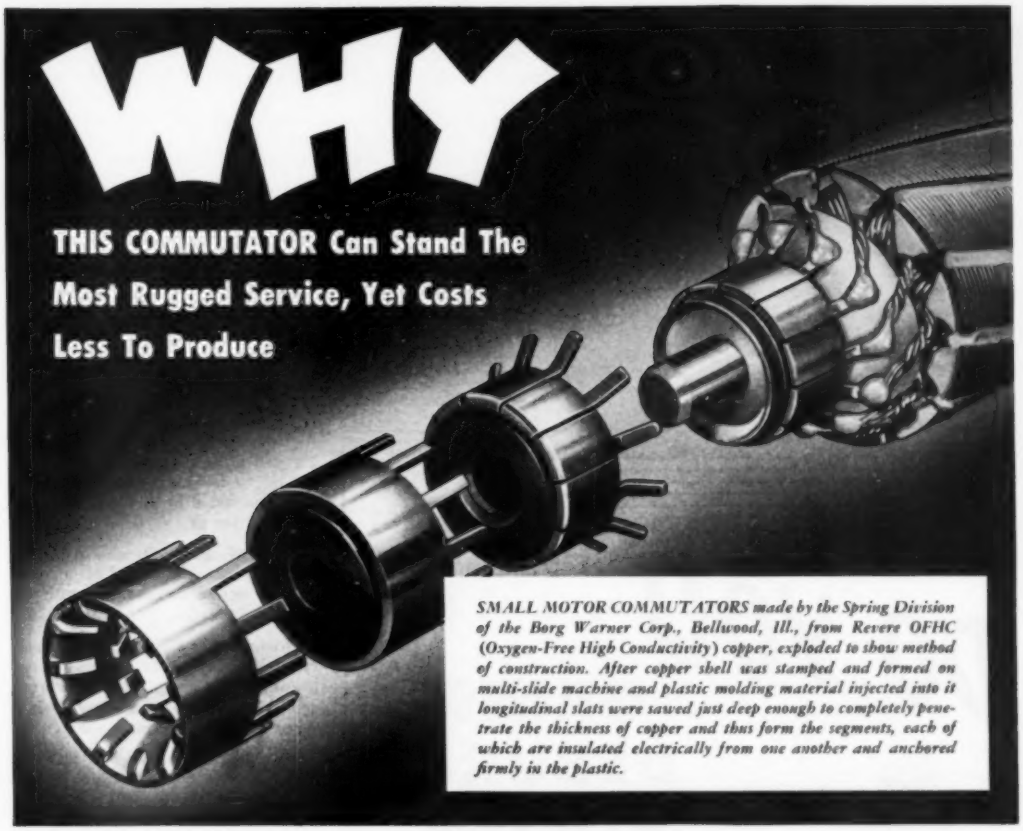
E. F. Houghton & Co. announce that **Orum R. Kerst** has been appointed to head its north section of the eastern sales division. Mr. Kerst was formerly New England representative for the company and will continue to have his headquarters in Worcester, Mass.

James G. Kerr, formerly instructor at Lehigh University, is now metallurgist at Los Alamos Scientific Laboratories, Los Alamos, N. M.

Gene D. Selmanoff, who was previously doing graduate work at the University of Minnesota, is now employed at the Institute for the Study of Metals at the University of Chicago.

WHY

THIS COMMUTATOR Can Stand The Most Rugged Service, Yet Costs Less To Produce



SMALL MOTOR COMMUTATORS made by the Spring Division of the Borg Warner Corp., Bellwood, Ill., from Revere OFHC (Oxygen-Free High Conductivity) copper, exploded to show method of construction. After copper shell was stamped and formed on multi-slide machine and plastic molding material injected into it longitudinal slats were sawed just deep enough to completely penetrate the thickness of copper and thus form the segments, each of which are insulated electrically from one another and anchored firmly in the plastic.

IT was quite a complex problem the Spring Division of Borg Warner Corp. dropped into the lap of Revere's Technical Advisory Service. They were getting set to manufacture commutators for small motors and they wanted to select the best material for the job.

Here were the specifications: The material had to be the hardest possible yet still able to take the extremely severe forming operation which was to be done in a multi-slide machine. High hardness was necessary in order to combine maximum wear resistance with the ability to withstand the extreme centrifugal force developed in small motors operating at high speeds. In addition, in the molding operation, which is done after the copper shells have been formed, it was necessary to hold the diameter of the shell to within .001" in order to prevent the plastic from flowing between the mold and the outer surfaces of the commutator. An equal tolerance was also imposed upon the height of the solid cylindrical portion for the same reason. Also of great importance was the need for the cylinder wall being almost absolutely flat.

Because of long experience with somewhat similar problems Revere recommended trial of OFHC (Oxygen-Free High Conductivity) copper, four numbers hard. This was tested along with several other metals. The OFHC alone was found to produce excellent parts, and with tolerances so close as to be almost unbelievable in this type of operation. All other types of copper failed at the very sharp bend where the anchoring lugs join the side of the shell.

An unusual feature of these commutators is the plastic material used in the core. Tough, and unusual in composition, it serves both as insulation and as a mechanical connection between commutator and shaft without use of a bushing and key.

To determine if these commutators could *really* take it, test motors in which they were used were speeded up to 35,000 rpm. Although the wiring in the rotors practically exploded at that speed, there were no failures in the commutators, Temperature tests up to 400° F. were also made. Here again there was no damage to the commutator, though the rotor wiring was badly damaged due to the combination of centrifugal force and decrease in wire strength. Once again the unusual combination of properties of Revere OFHC copper had played a part in helping another one of the country's leading manufacturers produce an outstanding product at less cost.

Perhaps this or some other Revere Metal can be of help in improving your product—cutting your production costs. Toward that end we suggest that you get in touch with your nearest Revere Sales Office.

REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, New York

• • •

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.
Sales Offices in Principal Cities, Distributors Everywhere.

Personals

John S. Billingsley ⊖, formerly Pittsburgh branch sales manager of Crucible Steel Co. of America, has been appointed central sales manager with his headquarters remaining in Pittsburgh.

Clarence B. Ringham ⊖ has been appointed factory manager of the heavy machinery divisions of Chain Belt Co., Milwaukee. He has been with the company since 1927 and was previously superintendent of plants in West Milwaukee.

Joseph C. Hess, Jr., ⊖ has been elected vice-president in charge of production of Leeds & Northrup Co., Philadelphia. Mr. Hess, who has been with the company since 1916, was previously assistant factory manager of the Germantown, Pa., plant.

Joseph C. Rintelen, Jr., ⊖ has joined the staff of Texas Western College as a professor of metallurgy in the division of engineering. Dr. Rintelen was most recently supervisor of the New Mexico experimental range of the research and development division of New Mexico School of Mines.

Alexander R. Troiano ⊖, formerly professor of metallurgy at the University of Notre Dame, has been appointed professor of physical metallurgy at Case Institute of Technology.

William J. Sparling ⊖ has been newly elected vice-president and manager of the chain and transmission division of Chain Belt Co., Milwaukee. Mr. Sparling joined the company in 1928 and has served in various capacities, most recently as works manager.

The Midvale Co. announces the following organizational changes: **W. L. Van Winkle** ⊖ has been appointed representative in Houston, Texas; **A. R. Gaus** ⊖, district sales manager of Pittsburgh, has had his territory extended to include Cleveland and he will be assisted by **J. W. Baer** ⊖ and **F. N. Satter** ⊖.

Gene W. Hinds ⊖, who graduated from the Colorado School of Mines in May, is now a metallurgist with the Geneva Steel Co., Provo, Utah.

Richard C. Pranik ⊖, formerly vice-president of Seaboard Screw Corp., is now assistant to the president, Western Automatic Machine Screw Co., Elyria, Ohio.

Everett L. Kenworthy ⊖, who graduated from the Colorado School of Mines in May 1949, is now working for the General Electric Co., Schenectady, N. Y., as a student engineer in the chemical and metallurgical training program.

Donald J. McPherson ⊖, who received his Ph.D. from Ohio State University in September 1949, has left his position as a research assistant at Ohio State University Research Foundation to become associate metallurgist at the Argonne National Laboratory, Chicago.

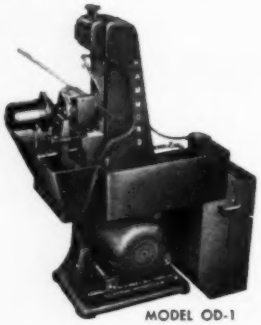
Glen W. Wensch ⊖, who has been working at the University of Illinois under a fellowship sponsored by the International Nickel Co., has completed his work toward his doctorate and has joined the research staff at Los Alamos Scientific Laboratory, Los Alamos, N. M.

Marshall W. Stevens ⊖ has been transferred from the Bridgeport General Electric works laboratory to the Elmira, N. Y., works laboratory as acting head.

Raymond N. Outzs ⊖, following graduation from Case Institute of Technology, has accepted a position in the Defiance, Ohio, plant of the General Motors Corp. as sand control technician and assistant to the plant metallurgist.

DO YOU

GRIND
DEBURR
POLISH
BUFF



MODEL OD-1

TUBES, RODS, BARS AND OTHER CYLINDRICAL SHAPES...PLUNGE CUT OR THROUGH-FEED

SEND SAMPLES...

For a Complete Engineering Report on Your Work. Send Us One Finished and Several Rough Samples. No Obligation.

MODEL OD-9

Hammond Machinery Builders INC.

1674 DOUGLAS AVENUE KALAMAZOO, MICHIGAN

This enlargement represents a 1/16" dot of fabric in a 51-gauge stocking. It shows the loop formation that provides such great elasticity.
Did you know? that in "20-denier" sheer nylon hose, the diameter of the yarn is .00197".
Did you know? that in a "51-gauge" stocking, each square inch of main leg fabric consists of 3536 loops.

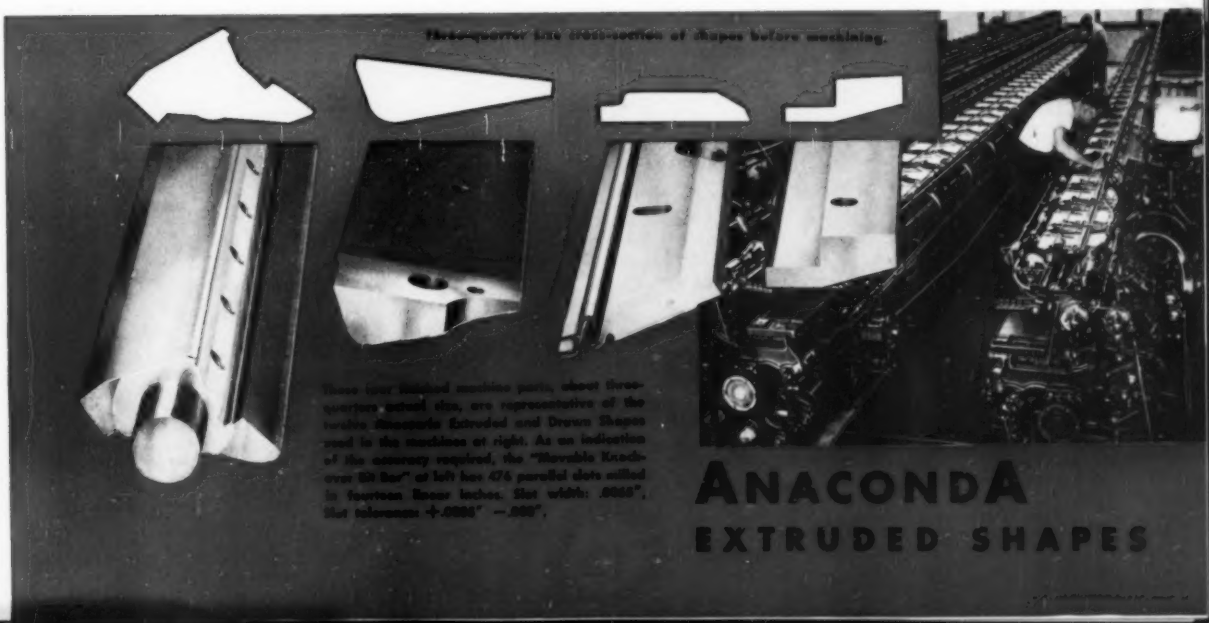
It takes 1,568,586 loops (AND FORTY MINUTES) to make a single 51-gauge stocking

High-Production Full-Fashioned Knitting Machines, 52'9" long and capable of knitting thirty stocking blanks simultaneously, are produced by the Textile Machine Works, Reading, Pa. With a total of 14,280 needles, each of its thirty sections lays a course of 476 loops in less than a second . . . yet it takes close to forty minutes to knit the one-and-a-half million loops required for a single 51-gauge stocking blank.

With so many moving parts, it wasn't easy to obtain the necessary smoothness of operation at high speeds. Precision, balance and long-wearing-and-bearing qualities had to be built into each of the machine's components—420 of which are made of twelve different Anaconda Extruded and Drawn Brass Shapes.

These shapes, made of wrought metal, are tough, strong, dense-grained and smooth-surfaced, with cutting characteristics that make them ideal for such precision-machined parts as those illustrated below. Besides, these parts are now being produced at a saving of 25 to 30% over the cast-brass sections they replaced.

The cost-paring advantages of Anaconda Extruded and Drawn Shapes are not limited to the textile industry. Produced in copper, brass, bronze or special copper alloys, they are available in an infinite variety of cross-sections. For further information, write to The American Brass Company, General Offices: Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.



ANACONDA
EXTRUDED SHAPES

There's nothing skin-deep about the beauty of this lamp

Too bad we don't have X-ray eyes . . . we'd be spared the disappointment of learning, too late, that the things we thought were solid brass—are not.

Not so with the "China-Brass" lamp illustrated above. It's typical of the entire line of solid brass table lamps, floor lamps, and smokers made by the Oxford Metal Spinning Co., Inc. of Philadelphia, one of the country's foremost lamp designers and manufacturers.

As a purchaser, you'd be well pleased with its handcrafted beauty—the durability of its solid brass construction—and, of course, its moderate price.

As its manufacturer, you'd quickly recognize the economy of using solid brass for its metal components. For in this plant—which annually produces hundreds of *different* patterns, shapes, and designs—not a single stamping or drawing die can be found. Instead, coils of Anaconda Spinning Brass are sheared to squares, centerpunched, cut to circles, and spun by hand. In this way, several hundred duplicates of an original design can be completed before a toolmaker could get halfway through a set of dies. Savings are passed on to the customer.

Using brass of just the right composition, grain size and temper is an important part of this low-cost, high-quality program. That's why "Oxford" consistently specifies "Anaconda Brass"—made by The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario.

Discs of Anaconda Sheet Brass and cut-length sections of Anaconda Seamless Tubes are used exclusively in spinning the Oxford lamp components illustrated.

ANACONDA COPPER & BRASS
for unsurpassed uniformity

What's the right X-Ray film?

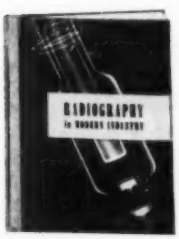
Product:
Gear housing
Material:
Magnesium
Thickness:
Walls varying ¼" to 1"
Equipment:
140-kv X-ray unit

ANSWER:

KODAK INDUSTRIAL X-RAY FILM, TYPE M

In a light alloy casting such as this, the radiographer is interested in discovering microporosity, as well as other irregularities that might be present. This requires the highest possible visibility of detail.

Therefore, Kodak Industrial X-ray Film, Type M, is chosen because this film has the highest contrast and finest graininess of all x-ray films.



RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practices, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get your copy from your local x-ray dealer—price $3.

Radiography . . .

another important function of photography

A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film.

Type M provides maximum radiographic sensitivity, high contrast, and exceptional detail under direct exposure or with lead-foil screens. It has extra fine graininess, and the speed is adequate for examination of light alloys at average kilovoltage and for much million-volt radiography.

Type A offers high contrast with about three times the speed of Type M, but with slightly more graininess. Used direct or with lead-foil screens for study of light alloys at low voltages, and of heavy steel parts with 1000-kv x-rays or radium.

Type K has medium contrast with high speed. For gamma ray work and for x-ray work where highest possible speed is needed at available kilovoltage without use of calcium tungstate screens.

Type F provides the highest available speed and contrast when exposed to x-rays with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead-foil screens.

EASTMAN KODAK COMPANY
X-ray Division · Rochester 4, N. Y.
"Kodak" is a trade-mark

Kodak

HEAT-
CORROSION-
ABRASION-
RESISTANCE

...OR
MACHINABILITY
IN

CASTINGS

by

Brake Shoe

● American Brake Shoe research and advanced foundry techniques can benefit you. When you refer your requirements to Brake Shoe, you get sound, clean, metallurgically correct castings, and machined rejects are low. You also receive the advantage of impartial recommendations as to metal types, such as:

Meehanite® — a series of controlled irons in 3 general groups to meet specific requirements; general engineering, heat resistant, corrosion resistant.

ABK Metal — a premium grade alloyed iron with outstanding abrasion resistance.

Engineered Gray Iron — a series of engineering cast irons with controlled properties and good machinability.

At Brake Shoe's large and well-equipped production foundries in Mahwah, N. J., Melrose Park, Ill., and Baltimore, Md., castings of widely used types can be made — light, medium or heavy weight, green or dry sand, or all core assemblies — as well as difficult or special purpose types.

Whatever your present or future needs for cast parts may be, send your specifications to Brake Shoe for expert recommendations.

AMERICAN Brake Shoe COMPANY

BRAKE SHOE AND CASTINGS DIVISION
230 PARK AVENUE, NEW YORK 17, N. Y.

Personals

William McCrabb, formerly superintendent of Dayton Rust Proof Co., has established a consulting service for metallurgy and plating in Dayton, Ohio.

Raymond F. Cathcart has resigned from his assistant professorship at Birmingham-Southern College to accept a graduate assistantship at the Missouri School of Mines and Metallurgy, Rolla, Mo.

Following graduation from Pennsylvania State College, **Emanuel C. Hirakis** has accepted a position with Cleveland Graphite Bronze Co., Cleveland, with a trainee status.

After graduating from the Colorado School of Mines, **Patrick M. Settanni** is now employed by Morvay & Co., Chicago, in charge of the heating department.

Herbert F. Brown is now a research assistant in the metallurgical section of the Knolls Atomic Power Laboratory of General Electric Co., Schenectady.

William A. Glaeser, who graduated from Cornell University this past June, is now with Clark Bros., Inc., Olean, N. Y., as mechanical engineer in its experimental department.

John B. Campbell, a recent graduate of the University of Michigan, has been appointed associate editor of *Materials & Methods*.

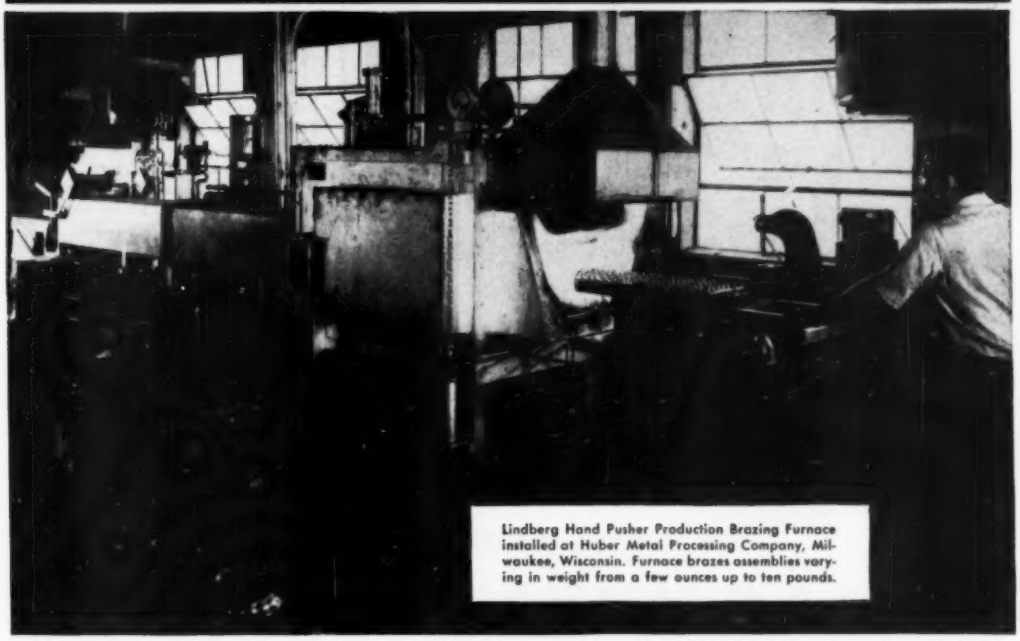
J. H. LaRose, formerly chief metallurgist at Packard Motor Car Co., Toledo division, is now research metallurgist at Ford Motor Co., Dearborn, Mich.

Edward Skillman, formerly with the Krause Plow Corp. of Hutchinson, Kan., is now design engineer with the J. B. Ehrsam & Sons Mfg. Co., Enterprise, Kan.

After graduating from Purdue University in June 1949 with a B.S. degree in metallurgical engineering, **Raymond Pritchard** is now employed as a special apprentice in the training program of Continental Foundry and Machine Co., East Chicago, Ind.

Cyril D. Kuhn has recently been transferred to the southwest as product representative for stainless steels for U. S. Steel subsidiaries, with headquarters in the Houston office of the Tennessee Coal, Iron and R.R. Co. He was formerly in the Chicago office of the Carnegie-Illinois Steel Corp.

Lindberg uses GLOBAR Heating Elements to Build Better Brazing Furnaces



Lindberg Hand Pusher Production Brazing Furnace installed at Huber Metal Processing Company, Milwaukee, Wisconsin. Furnace brazes assemblies varying in weight from a few ounces up to ten pounds.

Lindberg Engineering Company recognizes the many advantages of GLOBAR silicon carbide heating elements in designing furnaces for production brazing.

Because GLOBAR elements radiate clean, uniform heat to all sections of the furnace chamber, the production of consistently excellent work is assured. Moreover, the long and dependable service provided by GLOBAR heating elements cuts maintenance costs to a minimum. Rigid production schedules are easier to maintain. Improved working conditions also result from the use of furnaces equipped with GLOBAR heating elements. Clean, compact and noiseless, they offer maximum health protection to employees. Safe high temperature operation is realized through the elimination of explosion and fire hazards. Convenient, simple, and economical to operate... electric furnaces equipped with GLOBAR heating elements are being used in an increasing number of heat treating and kiln heating applications. Let us send you more complete information on installation and operating details. Write Dept. X-119, The Carborundum Company, GLOBAR Division, Niagara Falls, New York.

GLOBAR Heating Elements
BY CARBORUNDUM
TRADE MARK

"Carborundum" and "Globar" are registered trademarks which indicate manufacture by The Carborundum Company

STAINLESS STEEL
HEADS by

G. O. CARLSON, INC.

There are many advantages to buying stainless heads from G. O. Carlson, Inc. Not the least important is the fact that you place the entire responsibility in the hands of one capable organization. The same technical and production staff who produce Carlson Stainless plates to chemical industry standards, apply their skill to the production of heads to your specifications. A wide variety of head forming dies are available in both size and shape to suit your specific requirements. In addition to the dies to produce A.S.M.E. and Standard dished heads, dished and flanged heads, flared heads, flared and dished heads, we can supply special sizes spun to individual requirements.

G. O. Carlson, Inc., maintains a large stock of Stainless Steel Plates in many types and gauges to render prompt service in the production of heads.

Let G. O. Carlson, Inc. take the individual responsibility — send us your prints and specifications for quotations.

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Stainless Steels Exclusively

300 Marshalton Road, Thorndale, Pa.

PLATES • FORGINGS • BILLETS • BARS • SHEETS (No. 1 Finish)

District Sales offices and Warehouse distributors in principal cities

Personals

Lewis N. Rohrbach, who was formerly with the U. S. Air Corps as an inspector in the procurement of airplane parts, has opened a research laboratory for strategic minerals in Akron, Ohio.

Chester Werme has recently become associated with Central Screw Co. as research director for both the Chicago and Keene, N. H., plants. He was formerly vice-president and superintendent of Reed and Prince, Worcester, Mass.

Park Chemical Co., Detroit, announces the promotion of **Robert N. Lynch** to the position of sales manager of the heat treating materials division. Mr. Lynch has been with the company for the past ten years in metallurgical sales and service engineering capacities.

Wayne Laboratories, Waynesboro, Pa., announces that **Joseph S. Martin**, formerly associate director, has been appointed director.

Verne H. Schnee, formerly assistant director of Battelle Memorial Institute, has been appointed director of the University of Oklahoma Research Institute, Norman, Okla.

Jessop Steel Co., Washington, Pa., announces that **Frank B. Rackley** has been appointed executive vice-president. Mr. Rackley joined Jessop Steel as general manager of sales and then was made vice-president in charge of sales.

E. Richard Walter has been appointed midwestern sales representative of the Plastic Metals Div. of the National Radiator Co., Johnstown, Pa. Mr. Walter, who was formerly with Powdered Metal Products Corp., will make his headquarters in Chicago.

Robert F. Koenig, who has been with the Cleveland research division, Aluminum Research Laboratories, Aluminum Co. of America, since his discharge from the Army, has accepted a position in the Knolls Atomic Power Laboratory, General Electric Co., Schenectady.

Vanadium Corp. of America announces that **Gustav Laub**, formerly assistant vice-president and general manager of sales, has been elected vice-president in charge of sales.

F. Lewis Orrell, Jr., has been awarded the Titanium Alloy Mfg. Division's two-year fellowship at Ohio State University.

Noticeably greater ease in use comes with products made of Dow

MAGNESIUM

the world's lightest structural metal!

"Greater ease in use"—the product that can substantiate this claim has a tremendous sales advantage over its competitors. Magnesium has given this sales advantage to many products.

In a great variety of industrial fields magnesium has lightened tools and equipment, making them more efficient by reducing operator fatigue and increasing his output. Why magnesium? Because magnesium is the logical choice when lightness is desired. It's a full ⅓ lighter than aluminum, and only ¼ the weight of steel.

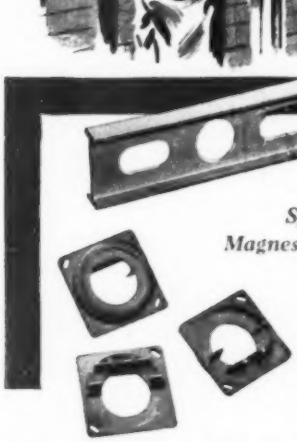
For all its lightness, magnesium is a remarkably strong and usable material. Its high strength-to-weight ratio makes possible strong, rigid designs with weight savings over other materials. Magnesium is readily available in all common forms and is easily and economically fabricated by well established shop procedures.

To see case studies showing how magnesium has improved products in many different fields, write for your free copy of "How Magnesium Pays."

THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

New York • Boston • Philadelphia • Washington • Cleveland
Detroit • Chicago • St. Louis • Houston • San Francisco
Los Angeles • Seattle

Dow Chemical of Canada, Limited, Toronto, Canada



Get Maximum Lightness, Speedy Fabrication with Low Cost Magnesium Extrusions and Die Castings

Wise manufacturers like the maker of this carpenter's level are profiting from the combined use of magnesium extrusions and die castings. Low cost magnesium extrusions are used to replace more costly formed or fabricated sections, while die cast magnesium parts greatly reduce the machining required because of their good surface finish and excellent dimensional accuracy.

Lighter Products Sell—make your product Magnesium Light

"King Tut tomb" ovens—installed in 1916 and still used successfully for long-cycle annealing of heavy castings.
BLAZING THE HEAT TREAT TRAIL
The first continuous controlled-atmosphere furnace heated by radiant tubes—producing economically at International Harvester Co. since 1936.
Three of six automatic overhead type controlled-atmosphere furnaces recently installed at International Harvester Co., Chicago.
Since 1916—
Holcroft

means **ECONOMY** in

MALLEABLE ANNEALING

From the tomb-type ovens of 1916 to the latest high-production units, Holcroft furnace engineering has led the way to new economies in malleable annealing. The radiant-tube-heated, controlled-atmosphere furnace—introduced by Holcroft in 1936—replaced heavy work containers with light-weight trays, giving notable savings in time and fuel. The Holcroft overhead furnace design cut time and labor to a new low; and we can cite many other advantages provided by Holcroft trail-blazing.

Holcroft furnace design is based on *complete metallurgical and engineering service*. We design each furnace for its individual application, selecting *without bias* the elements best suited to the job; and in so doing, we constantly develop improved features and processes. As a result, Holcroft furnaces meet every production requirement *at minimum over-all cost*—for malleable annealing and for *every other* heat treating process.

For these reasons, it will pay you to have us quote on your next heat treating installation. We cordially invite your inquiries.

SINCE 1916 Holcroft AND COMPANY

BUILT BY HOLCROFT & COMPANY DETROIT-MICH.

PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

6545 EPWORTH BLVD. DETROIT 10, MICHIGAN

CHICAGO 3
C. H. MARTIN, A. A. ENGELHARDT
1017 PEOPLES GAS BLDG.

CANADA
WALKER METAL PRODUCTS, LTD
WALKERVILLE, ONTARIO

HOUSTON 1
R. E. McARDLE
5724 NAVIGATION BLVD.

Electropolishing

(Starts on p. 696)

4. Rinse specimen block in methyl alcohol or rectified spirit, first holding the upper portion of the jig and finally removing specimen block from jig and rinsing this separately to remove the chrome-acetic solution which has been trapped between the back face of the specimen block and the jig.

5. Etch in 2% nital or other preferred etch.

6. Wash in running water.

7. Rinse in acetone.

7a. Rinse in acetone. (The use of two rinses means that the second one will remain relatively free from water.)

8. Shake off surplus acetone quickly and dry in warm air.

The above procedure is based on the following facts:

1. In our experience a satisfactory etch does not result if the specimen block is simply washed in water after polishing and before etching. This may be due to a passivating action of the aqueous chromic acid which inevitably comes into contact with the specimens.

2. The current must not be passing through the cell unless the jig is rotating.

3. It is unnecessary to keep the current flowing through the cell while the specimens are being removed, as must be done with some polishing electrolytes.

It is unnecessary to use fresh acetic acid and alcohol rinses each time. A reasonable build-up of chromic acid in the acetic rinse and chrome-acetic acid in the methyl alcohol or rectified spirit rinse is permissible before discarding. The rinsing and etching reagents may be conveniently kept in 250-ml. jars.

Aging of the Electrolyte

Although the chemical reactions which occur during aging are evidently very complex, it appears that the basic factors which cause the electrolyte to deteriorate can be stated fairly simply:

1. Absorption of water from the atmosphere, owing to the hygroscopic nature of the electrolyte.

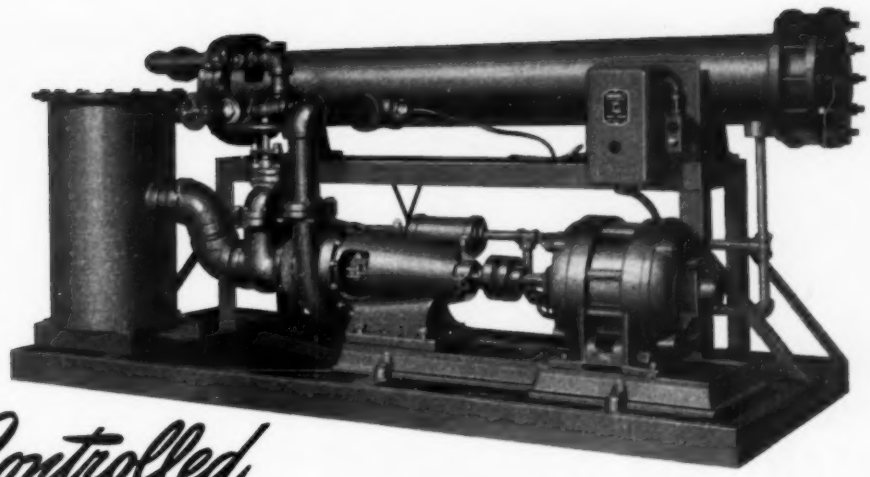
2. Loss of water by electrolysis.

3. Loss of acetic acid by evaporation.

4. Anodic dissolution of the steel specimens and cast-iron particles causing a build-up, mainly of iron, in the electrolyte, since no plating-out occurs on the cathode. A small amount of iron is actually beneficial but once the optimum figure has been reached any further increase has a deleterious effect.

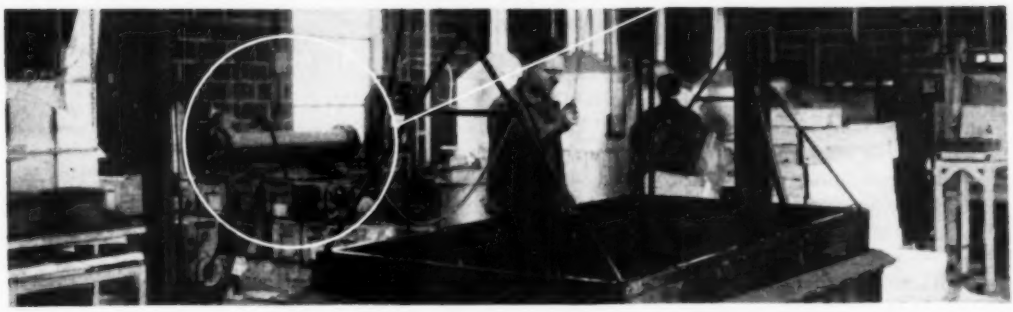
5. Reduction of chromic acid ($Cr^{6+} \rightarrow Cr^{3+}$) by some of the hydrogen produced at the cathode.

(Continued on p. 712)



Controlled

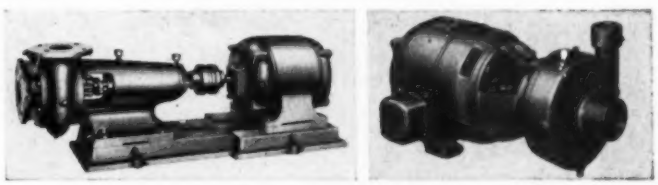
QUENCHING PAYS DIVIDENDS



Old-fashioned quenching methods may be eating up a substantial percentage of your profits. By installing a B & G *Hydro-Flo* Oil Cooler, you can eliminate the losses caused by excessive rejects—make an "inside profit" by cutting operating costs.

The B & G *Hydro-Flo* Oil Cooler maintains a constant temperature and correct turbulence in the oil bath . . . assures uniform quenching conditions which mean uniform quality in the finished product. *Hydro-Flo* Cooler units are easy to install—completely factory-assembled, ready for connection to oil and water lines. Get the facts today.

Send for this combined Catalog and Simplified Selection Manual.



A complete line of flexible and close-coupled centrifugal pumps. Send for engineering data.

Hydro-Flo* **OIL QUENCHING SYSTEMS**

BELL & GOSSETT COMPANY

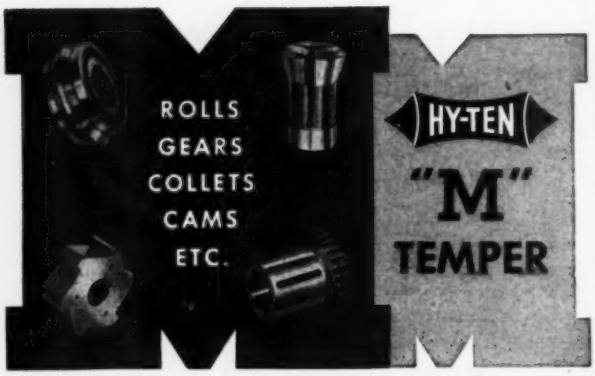
Dept. BF 16, Morton Grove, Illinois

Heat-treating equipment since 1916

*Reg. U. S. Pat. Off.

OVER ONE HUNDRED YEARS OF CONTINUOUS SERVICE. ROUNDS, SQUARES, FLATS, HEXAGONS, OCTAGONS

BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS.



THE ALLOY STEEL THAT'S *MEANT FOR PUNISHMENT*

"M" TEMPER oil hardening steel was developed specifically for such vital, punishment-taking parts as dies, cams, collets, forming rolls, clutches, gears, etc. "M" TEMPER effectively combines high hardness with maximum toughness, minimum distortion, extreme density and great strength – properties that ideally combine to resist wear and breakage. This grade develops the advantages of the powerful alloys – chromium, nickel and molybdenum. Moreover, "M" TEMPER has excellent forging properties and is readily machinable in the annealed condition. Although low in cost, "M" TEMPER has non-deforming properties comparable to, and in many cases superior to, much more expensive steels.

WL *steels are metallurgically constant. This guarantees uniformity of chemistry, grain size, hardenability—thus eliminating costly changes in heat treating specifications.*

Write today for your FREE COPY of the Wheelock, Lovejoy Data Book. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.

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HY-TEN and AISI

Electropolishing

(Starts on p. 696)

(Any oxidation occurring at the anode is insufficient to counteract this.) The presence of appreciable quantities of reduced chromium in an aged solution has been confirmed by chemical analysis. This reduced chromium serves no useful purpose.

Experience shows that if the electrolyte is not kept airtight when not in use, it will deteriorate rapidly. As the water content of the electrolyte is critical for optimum results we conclude that this deterioration is caused by an increase in water content brought about by the absorption of a greater amount of water from the atmosphere than is lost by electrolysis.

The loss of acetic acid which also occurs if the cover for the cell is not airtight is in general comparatively slight and insufficient to account for the deterioration which occurs. This is confirmed by the fact that it has not been found possible to rejuvenate a deteriorated solution by adding acetic acid.

From the above remarks it will be clear that it is vital to provide an airtight seal for the cell when it is not in use. If the cooling coil is left in position during these idle periods, the design of a really efficient airtight cover is rendered somewhat difficult by the presence of the inlet and outlet tubes. Pending satisfaction in this direction, we remove the cooling coil at the conclusion of polishing and place a soft rubber sheet over the cell and on top of this a heavy weight, both the underside of the weight and the top of the cell being turned or ground flat for close contact.

Specimens Unsuitable for Electropolishing

Because of the preferential attack which occurs at discontinuities and on nonmetallic inclusions, specimens which are to be examined unetched for fine cracks or for the type and distribution of the nonmetallics are not suitable for electropolishing.

Etched structures are also spoiled if the inclusion content is high. Notably, this rules out free-cutting steels and graphitic irons.

High-alloy steels containing complex carbides (for instance, high speed steels) are also unsuitable for electrolytic treatment. However, certain stainless steels containing

(Continued on p. 714)

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FOR WELDABILITY

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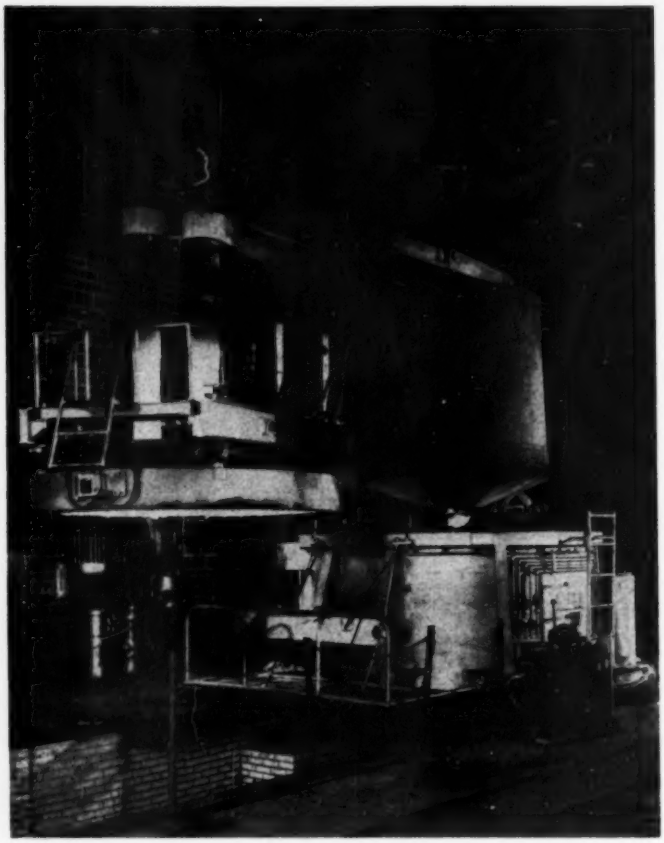
MAKERS OF FERRO-ALLOYS

CHEMICALS AND METALS



Recharging a Moore Rapid Lectromelt Furnace, like the size OT pictured above, is a simple, time-saving operation. You merely raise the roof hydraulically, swing it aside, then dump the scrap charge. In a mere matter of moments your Lectromelt is melting again, producing more in less time. This great reduction in down time, plus substantial labor savings, will bring your operating costs down.

Lectromelt furnaces are available in capacities ranging from 100 tons to 250 pounds. Write today for complete information.

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MOORE RAPID Lectromelt FURNACES

manufactured in: CANADA, Lectromelt Furnaces of Canada, Ltd., Toronto 2; ENGLAND, Birlec, Ltd., Birmingham; SWEDEN, Birlec Elektkougnar A/B, Stockholm; AUSTRALIA, Birlec Ltd., Sydney; FRANCE, Stein et Roubaix, Paris; BELGIUM, S. A. Belge Stein et Roubaix, Bressoux-Liege; SPAIN, General Electrica Espanola, Bilbao; ITALY, Forni Stein, Genoa.

Electropolishing

(Starts on p. 696)

fine globular carbide (mainly chromium carbide) have been successfully electropolished.

The only steels in the plain carbon and low-alloy class which appear to need special treatment are those with more than about 0.50% carbon in the spheroidized condition. For good results, these seem to require the lower current densities and therefore the percentage area occupied by these specimens on the working face of the block should be as high as possible — preferably 50% or more.

Reproducibility of Results

If the operating conditions set out above are rigidly adhered to, good results can be obtained every time. However, should the directions not be followed or if the solution is overaged, then an etched patch of varying size will probably appear on the working face of the block, generally in the central region.

Since the speed of agitation, voltage, and working gap between specimen and cathode are all fixed, microspecimens can be electropolished satisfactorily by a relatively unskilled operator if the apparatus is set up properly.

Electrolytic Etching

By reducing the current to only 0.025 amp. it has been found possible to etch certain stainless steels electrolytically in the above apparatus very satisfactorily.

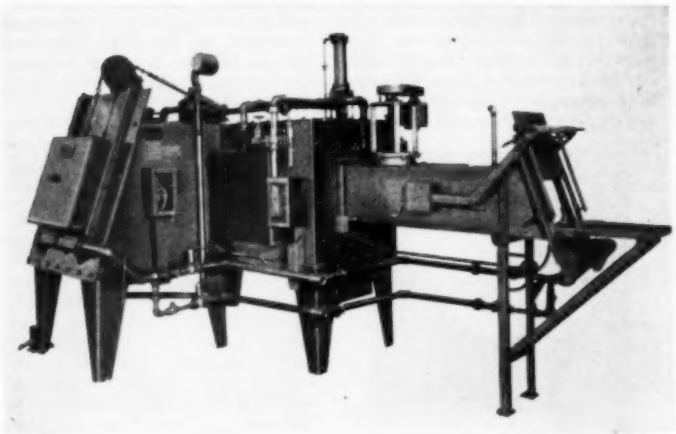
The procedure is as follows:

1. Polish as usual.
2. As soon as the polishing time has expired, and leaving the specimen in place, reduce the voltage until the current passed is only 0.025 amp.
3. Switch off the jig motor.
4. Leave for a suitable time.
5. Switch off current and remove specimens from cell.
6. Wash in water and dry. (Rinsing in acetic acid and methyl alcohol is not required.)

Austenitic stainless steels require about 20 min. etching. Ferritic and martensitic stainless steels require different times according to the physical condition of the specimens. Thus in the annealed condition, 5 min. may suffice, whereas in the hardened condition, 20 min. or more may be required.

The four micrographs on p. 699 were electropolished in the apparatus under optimum conditions.

ENGINEERING DIGEST OF NEW PRODUCTS



FURNACE FOR BRIGHT HARDENING HIGH SPEED STEELS: The molybdenum, 18-4-1, 18-4-2, or cobalt-type high speed steels can be hardened virtually bright and totally free from decarburization or carburization according to Lindberg Engineering Company's announcement of this new atmosphere hardening furnace.

Primarily developed to harden precision high speed tools that have fine cutting edges and cannot be ground or cleaned after hardening, the furnace is unique in construction and looks odd in comparison to the conventional preheat and high heat furnaces of the past. Known as the "L-Type", the furnace consists of preheat, high heat, and quench all built into one complete unit. The odd and unique part of the design is that the preheat is built at a right angle to the high heat. The quench-unit follows directly behind the high heat unit and is another very unique part of the design. This unit is designed to quench the steel by means of forced convection, cooled, protective atmosphere. Sections of high speed steel up to 2 in. can be fully hardened by the atmosphere quench. Since the steel does not contact the air until after the preheat, hardening and quench are completed, bright results which are totally free from decarburization or carburization can be obtained.

For further information circle inquiry card number 859

MICROHARDNESS TESTER: A new microhardness tester model MO, mechanically operated and recommended for those interested in light-load testing where a fully automatic model is not warranted, is announced by Wilson Mechanical Instrument Co., Inc.

It applies loads of from 1 to 1000 g., and may be used with either the Knoop or 136° diamond Pyramid indenter. Load is applied under dash pot control, speed of which may be varied from less than 0.040 in. per min. to as fast as testing permits without impact influencing the results. Both the rate of application and duration of applied load may be controlled. An outstanding feature of this model is a special arrangement for removing the load so that the operator does not have to touch the instrument until the indenter is out of the impression. This is an important feature in obtaining clean-cut impressions not subject to distortion.

For further information circle inquiry card number 860

ROUND EDGE FLAT WIRE: Round edge flat wire in a nickel or chrome finish on steel base is furnished by American Nickeloid Company. It is available finished on one or both sides in 0.035 to 0.125 in. thickness, and $\frac{1}{8}$ to 2 in. widths. Standard length in nickel finish is 71 or 142 in. cut into two parts, no one part exceeding 95 in. In chrome finish, lengths are 70 or 120 in. cut into two parts, no one part exceeding 94 in.

For further information circle inquiry card number 861

HEAVY-DUTY ARC WELDER: A new heavy-duty arc welder, known as the Wilson 36A Yellow Jacket, is built in 300 and 400-amp. sizes by Air Reduction Sales Company. The Yellow Jacket is especially suitable for pipe-line work, construction jobs or any work where ruggedness and durability are important factors.

The Yellow Jacket is a direct current, 40-volt, NEMA-approved, variable voltage generator. Current output is simply controlled by a sturdy hand wheel mounted on the control cabinet. Close calibration of the current dial eliminates the need for meters.

For instant recovery voltage over short circuit, the 36A generator is self-excited, with excitation of the mainfield obtained through an auxiliary brush. Welding terminals are conveniently located and adequately spaced to prevent accidental shorting between the lugs of the welding cables. The belt drive reduces vibration problems in the field by automatically compensating for slight misalignments.

The 36A is powered by a sturdy six-cylinder industrial engine and is available in stationary or portable models.

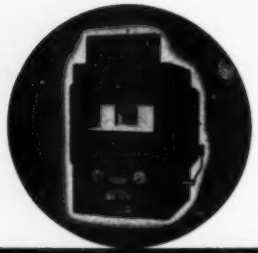
For further information circle inquiry card number 862

ROLL FORMING MACHINE: Roll forming machines which form, curve, emboss and cut in one continuous operation, are built in standard sizes to take material up to 5 inches wide and 20 ga. thick by American Roller Die Corp.

Larger sizes for material up to 50 in. wide and $\frac{3}{8}$ in. thick may be

supplied. Molding, beading, metal roofing, automotive parts, tubing, weather-stripping and various other shapes may be formed on the machine.

For further information circle inquiry card number 863



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HIGH TEMPERATURE "UNIT-PACKAGE" ELECTRIC BOX and MUFFLE FURNACES for melting, sintering, heat treating, ignitions, etc.

Write for Bulletins 315 and 515.

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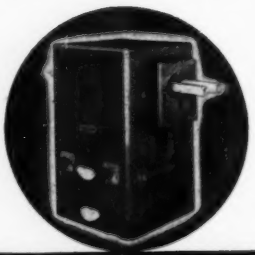


BURRELL
TUBE FURNACE

HIGH TEMPERATURE "UNIT-PACKAGE" ELECTRIC TUBE FURNACES for determination of carbon or sulfur by combustion and for experimental or production purposes.

Write for bulletin 310.

BURRELL 1942 FIFTH AVE PITTSBURGH 19 PENNSYLVANIA

NEW PRODUCTS

SURFACE TREATMENT CHEMICAL: A new type surface preparational material for cleaning surfaces prior to organic finishing has been developed by Enthone, Incorporated.

This product is a liquid that contains oil-displacing chemicals that quickly dislodge oil, grease and other

organic material from the surface of metals so that they can be quickly rinsed off with water or wiped off with a cloth. The material also contains phosphating and other rust removal chemicals that quickly dissolve rust, oxide and scale while the oil removal agents are operating.

For further information circle inquiry card number 864

COMBUSTION SAFEGUARD: New 1300 series Flame-otrol combustion safeguard for industrial and commercial fuel-fired furnaces, ovens, kilns

and other heating equipment is announced by the Wheelco Instruments Company.

This new Flame-otrol is capable of detecting the presence or absence of a gas or oil flame of any type of burner, eliminating the need for specially designed equipment.

For further information circle inquiry card number 865

INDUCTION HEATING UNIT: A new induction heating unit incorporating several unusual features is announced by the High Frequency Heating Division, Lindberg Engineering Company, and described in Bulletin T-1420.

The Type LI-25 has a conservatively rated output of 25 kilowatts at 100% duty cycle with a normal frequency of 450,000 cycles per second. Units are available for operation on 230, 460 and 550-volt, 3-phase, 60-cycle power. A manually operated tap switch allows the operator to compensate for line voltage changes.

Servicing is greatly simplified by "Checklite", a unique system of indicating lamps which instantaneously reveals abnormal conditions at any one of the protective devices. All electrical overloads can be reset by the flick of a switch on the front operating panel. Work coils are protected from burn-out by an interlocked solenoid valve which controls work coil cooling water.

For further information circle inquiry card number 866

FURNACE RETORT: A new furnace retort is announced by Stanwood Corporation.

The unit features a one-piece bottom seal ring of greater rigidity than the fabricated type formerly used.

The ring will hold its shape throughout the life of the retort, assuring a tight seal and easy installation or removal from the furnace. The highly satisfactory top seal ring, which is an integral part of the retort, has been retained.

For further information circle inquiry card number 867

NEW PRODUCTS

METAL CUT-OFF: Capacity cuts up to 3-in. solids and 4-in. pipe in both ferrous and nonferrous metals are obtained with this "swing-cut" abrasive metal cut-off machine through

the elimination of all belt drives with a 5 h.p. geared-in-head motor.

Rigid construction plus positive holding increases wheel life accomplishing straight cuts to close tolerances with a minimum of burr. Cutting at extremely high speeds reduces the possibility of burn in the metal and eliminates the undesirable necessity for wet cutting in many materials, according to Stone Machinery Company.

A fast acting self-centering vise mounted on a quickly adjusted swivel plate, calibrated in degrees, provides for a speedy change from straight or ninety-degree cutting to any desired angle.

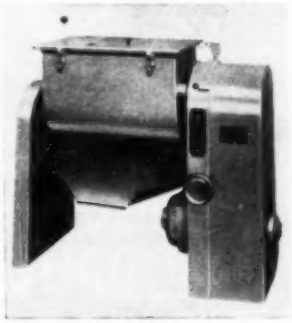
For further information circle inquiry card number 868

HEAVY DUTY ELECTRODE HOLDER: A new heavy duty electrode holder operating through 700 amps. and ⅜-in. electrodes is announced by Martin Wells, Inc.

Silver-brazed cable connections in size 4/0 cable are recommended for use with this holder on 600-700 amps. Electrodes are held and fixed in 60 or 90° position by cam bulldog action. The manufacturer states the cam action gives positive contact on the electrode and reduces the heating on both the stub and holder.

For further information circle inquiry card number 869

METAL MIXERS: A new series of mixers has been developed by F. J. Stokes Co. which are completely redesigned for greater operating efficiency. Available in 50, 100, 200 and 300-lb. capacities, the new Stokes Series 21 mixers incorporate the following improvements: (1) dust-tight lids provided with rubber gasket to prevent escape of dust; (2) positive safety devices on the lid, so that the motor shuts off when the lid is raised; (3) variable speed control, with agitator speeds from 21 to 42 r.p.m.; (4) all-welded rigid construction with mixer designed for easy cleaning; (5) completely enclosed drive to protect working parts from dust and dirt; (6) adjustable discharge chute, which can be tilted to any height; (7) simplified dumping mechanism, with safety catch for locking mixer in po-



sition; (8) pushbutton stop-and-start control, with job button for jogging agitator around when dumping; (9) perforated trough available to admit solutions of binders or flavorings.

For further information circle inquiry card number 870

CLEANER CONDITIONER: A new acid-type cleaning and surface-conditioning material is announced by Oakite Products, Inc. Designed to remove rust, oxides, grease, oils and shop soils from metal surfaces, and to prepare ferrous metals and aluminum for sure-grip adhesion of paint, lacquer and enamel finishes.

Oakite Compound No. 33 possesses notable detergent and solvent properties, and may be used for prepaint cleaning of large steel or aluminum parts or sheets by wipe-on method.

Where light rust is the principal soil on steel parts, time and money may be saved by using Compound No. 33, thus eliminating the need for separate pickling and rinsing operations.

For further information circle inquiry card number 871

INSTANT, DIRECT
Temperature Readings
Accurate to within a
Fraction of a Scale
Division with

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Trade Mark Reg. U. S. Pat. Off.
HAND PYROMETERS

Specify XACTEMP PYROMETERS wherever a quick, accurate temperature determination is needed. Used for surface temperatures of welds, welded rail ends, billets, slabs, heated rollers, forgings, ovens, hot plates, furnace walls—for general inspection in furnaces, lead and salt pots, galvanizing tanks, core ovens, type metal, etc. Long-life cast aluminum and brass construction. Medium resistance, fast-acting indicator, provided with Alnico V magnet—direct reading dial starts at 50° F. or 60° F. Simple, easy to operate—no adjustments necessary—always ready for use. Will take most types of thermocouples. A full line of thermocouples available from stock.

FOUR MODELS

Catalog No.	Range	Thermocouple
LT 800	60-800 F.	Iron-Constantan
LT 810	60-1200 F.	Iron-Constantan
LT 820	60-1600 F.	Iron-Constantan
LT 830	50-2500 F.	Chromel-Alumel

PRICE WITHOUT THERMOCOUPLE $39.50

Ask also about XACTEMP PYROMETERS for taking temperatures of molten non-ferrous metals

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The five Aluminum Bronze and two Tool Steel electrodes are for special applications such as building up or facing bearings, tools and dies.

Write for descriptive data.

M & T Hard Facing electrodes are members of the "Select 70"—a group of seventy outstanding electrodes offered by M & T—along with M & T AC and DC welding machines and M & T accessories—to give you everything needed for arc welding—arc welding of top-notch quality.

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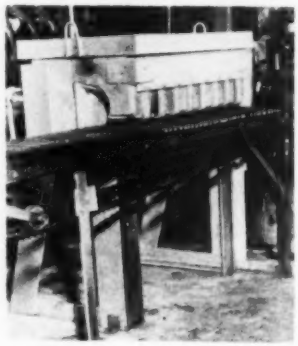
NEWARK PHILADELPHIA PITTSBURGH SAN FRANCISCO TORONTO

NEW PRODUCTS

END HEATING FURNACE: A distinctly different type of end heating furnace employing recent developments in high speed heating design has been developed by Gas Appliance Service.

Versatile in its applications, the furnace is used for forging, swaging, upsetting, threading, hardening and annealing. The ends of the pieces



being heated are entirely enclosed in flame, thereby limiting scale formation.

When in operation, the curved refractory section of the Roto-Flame becomes completely incandescent, providing additional radiant heat from this surface. The shape of the refractory also serves to carry the flame inward, instead of letting it escape through the front slot. Fuel consumption is low; any commercially available gas may be used. The unit is fired with a relatively large number of small, high pressure burners.

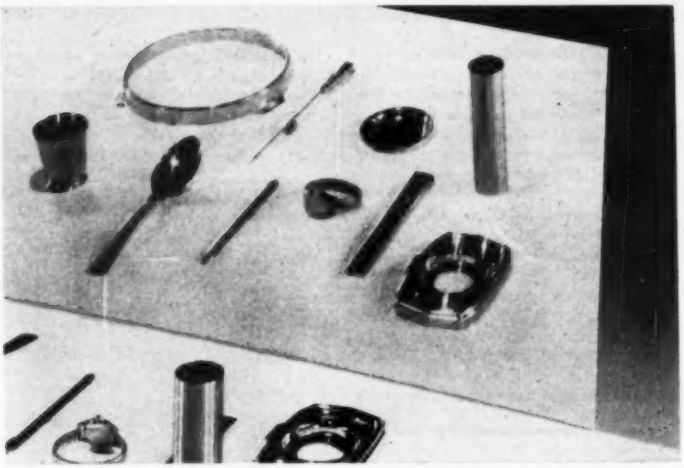
For further information circle inquiry card number 872

MULTIPLE POINT PYROMETER: A new model thermo-electric pyrometer is introduced by Thermo Electric Co. This multi-point pyrometer and quick coupling connector panel assembly is designed for indicating temperatures from one to six thermocouple locations at operating ranges from 75 to 400, 1000, 1600 and 2300° F., and minus 300 to plus 300° F. or equivalent Centigrade scales.

The polarized, quick coupling plug connects the pyrometer to any one of the six thermocouple jacks. Greater accuracy of temperature readings is obtained by this method because all plugs and jacks are of thermocouple materials.

For further information circle inquiry card number 873

ENGINEERING DIGEST OF NEW PRODUCTS



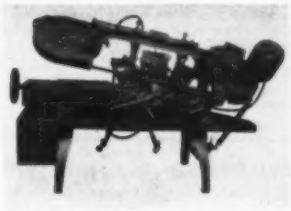
BRIGHT ANNEALED STAINLESS STRIP STEEL: A new 18-8 bright annealed stainless strip steel is announced by the Wallingford Steel Company.

The unretouched photo shown illustrates diversified applications for the new strip steel. Available in widths up to 15 in. and thicknesses to 0.070, this new product is claimed by the manufacturer to eliminate rough and finish grinding, due to its exceptionally bright finish.

For further information circle inquiry card number 814

AUTOMATIC BAR FEEDING DEVICE: A new automatic bar stock feeder that converts horizontal metal cutting band saws into fully automatic cut-off machines is announced by the Wells Manufacturing Corporation. This device attaches easily and without interference with normal operations of the saw.

Projection of material in various sizes and shapes is accomplished by an air actuated (60 to 80 pounds pressure) spiral roller drive, together



with positive air control of saw frame, during each cutting and resetting cycle, makes the multiple cutting action completely automatic.

For further information circle inquiry card number 815

Better testing equipment

to improve your products

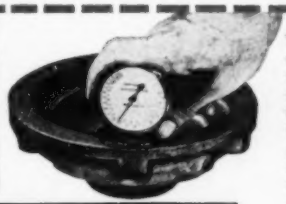
Compare the prices shown here with those currently quoted for other units of test equipment designed for the same general purposes. These prices are not only lower but the performance of Dietert control equipment is in every case equal to or superior to any other units available.

With the Dietert Carbon Determinator, you can run ACCURATE quantitative carbon tests on metals or other materials in the short space of two minutes.

The PRICE is $235.00

The Dietert Sulfur Determinator provides you with the means of getting the sulfur content of metals and other materials with precision. The equipment and the analytical procedure meets the tentative ASTM Standards for the determination of sulfur in steels.

The PRICE is $153.00



The Dietert Brinell Hardness Reader can be used successfully by any one in your plant who can read a dial. No judgment is necessary, no charts or tables to consult and no figuring to do. It makes hardness testing foolproof. The Brinell Hardness Reader replaces the measuring microscope. It measures the depth of the Brinell impression rather than the diameter. The dial is graduated in Brinell Hardness Numbers.

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ENGINEERING DIGEST OF NEW PRODUCTS

BLIND FASTENER: A new blind fastener known as the Bolt-Retaining Speed Clip for attaching small parts and accessories to metal panels is announced by Tinnerman Products, Inc.

New speed clip is applicable for many blind assembly operations where tapped accessories — such as handles, knobs, plates, medallions, brackets and ornaments — are attached to metal panels.

The new clip is produced for a 10-24 screw size and requires a panel hole 0.325/0.335 square with a panel thickness of 0.050/0.060.

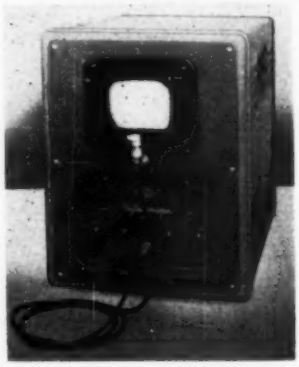
For further information circle inquiry card number 876

REFLECTOSCOPE: A new model of reflectoscope—portable, ultrasonic instrument for testing metals incorporating functional changes in styling and external design, together with modifications which facilitate interpretation of test results is announced by Sperry Products, Inc.

Designated as Type UR, Style 50E351, the new instrument replaces the company's previous model, Type SR05.

An improved pattern of square-wave "inch markers" on the horizontal axis of the screen facilitates interpretation of test results. Also, a new "reject" control gives the operator additional control of sensitivity by rejecting indications of small defects which do not affect the performance of the part or material under test.

The Reflectoscope is used regularly in many plants for testing steel



billets, forgings, castings, finished stock, and a wide variety of machined parts including shafts, axles, rolls, piston rods, bolts, and studs. Welds in steel plate, pipes, and containers are tested by means of the angle-beam technique, in which ultrasonic vibrations enter and leave the tested material at an acute angle to the surface, and travel through the material by successive reflections between the surfaces.

Typical users of the Reflectoscope include steel mills, foundries, railroads, fabricators and processors of tool steels, aircraft and automotive manufacturers, metal working plants, ordnance plants, and maintenance departments.

For further information circle inquiry card number 878

ATTACHMENTS FOR ELECTRON MICROSCOPE: Three new accessories permitting specialized application of the RCA Electron Microscope are announced by the Scientific Instruments Section of the Radio Corporation of America Engineering Products Department. They include a Type EMN-1 Charge Neutralizer, a Type EMX-1 Focusing Magnifier, and a Self-Bias Gun Kit.

The EMN-1 Charge Neutralizer is designed to neutralize charges produced on diffraction specimens by the primary electron beam of the microscope, which may cause distortion of the image.

The Type EMX-1 Focusing Magnifier enables the microscope operator to focus upon a certain portion of the image field with greater precision. It permits direct viewing of the image at 150,000 magnifications, and greatly improves the quality of electron micrographs obtained.

Simplified alignment, greater stability, and improved over-all performance of the microscope are made possible by the Self-Bias Gun Kit, MI-12986. This attachment provides intense illumination with lower beam current. The intensity of the electron beam produced by the gun is controllable, making it possible to obtain maximum resolution in studies of a wide range of specimens.

For further information circle inquiry card number 877

LEAD ALLOY: A new lead alloy for use in the chromium plating industry is announced by the National Lead Company.

Nalco Metal is used for tank linings, anodes and heating-and-cooling coils and is substantially more resistant to the corrosive and pitting action of chromic acid solutions. With the new alloy, anodic treatments of linings and coils are not necessary.

In sheet form the new alloy is as easily cut, trimmed and shaped to the contours of the tanks as the lead alloys previously used. In pipe form Nalco Metal is readily coiled or looped and bound, clipped or blocked into units of any desired design or form.

For further information circle inquiry card number 879

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

880. Abrasive Segments
Four-page bulletin ESA-158 explains how segments are used, their advantages, discusses abrasives and bonds employed. Includes grain and grade recommendations of abrasive segments for both surface grinding and machine knife grinding operations. *Simonds Abrasive Co.*

881. Abrasive Wear
Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

882. Acid Diluting Equipment
"Karbate" brand sulphuric acid diluting equipment is described in new catalog M-8806A. *National Carbon Co.*

883. Alloy
Tenzaloy, new aluminum-magnesium-zinc alloy reduces costs and casting weight and provides strength without heat treatment. Described in technical bulletin. *Federated Metals Div.*

884. Alloys
New 40-page booklet featuring articles on company history, how to specify and order phosphor bronze, nickel silver, cupro nickel, beryllium copper and miscellaneous alloys along with a chapter on temper and many useful tables and data on weights and tolerances. *Riverside Metal Co.*

885. Alloys, Fabricated
New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

886. Aluminum Alloys
New condensed reference chart giving the properties of most of the aluminum alloys available in the form of wrought products. *Revere Copper and Brass, Inc.*

887. Aluminum Roll Forming
New catalog 44-01 describes aluminum roll-formed shapes. This catalog tells how the manufacturer can reduce scrap and speed up production by the use of rolled forms in long lengths. Also outlines the ease of bending, accuracy and smoothness of finish of this type of shape. *Reynolds Metals Co.*

888. Bars, Forging
There is a stainless steel "tailored" to fit your specifications for chemical and physical properties. Write for 112-page booklet of forging data, "Evaluating the Forgeability of Steels". *Timken Roller Bearing Co.*

889. Camera, High Speed
"Magnifying Time", a new folder describing high speed camera capable of 1000 to 3000 pictures per second. Particularly adaptable for close inspection in machine tool operations and also for measuring flow of liquids as in chemical mixers, coolant flow, etc. *Eastman Kodak Co.*

890. Carbonitriding Steel
New 6-page booklet, "Carbonitriding of Steel", discusses its history, advantages, theories, atmospheres, equipment, operating conditions and industrial applications of this process. *Armour Ammonia Division.*

891. Castings
Complete information on numerous applications for microcasting is given in 16-page booklet, "New Horizons for Microcasting". *Austenal Laboratories, Inc.*

892. Castings
New 72-page book entitled "Castings by Howard" contains information on zirconium and rare earth magnesium-alloying elements. This book also includes helpful, understandable information on the casting of aluminum, magnesium, brass, bronze and semi-steel as well as numerous tables showing mechanical properties, chemical analysis and physical characteristics of these metals. *Howard Foundry Co.*

893. Castings
20-page booklet, "Misco Precision Castings", contains valuable technical information for manufacturers requiring small, accurate, alloy steel parts in quantity. *Michigan Steel Casting Co.*

894. Castings
Bulletin No. 7 describes how National Erie serves the metal industry by supplying medium and small castings by controlling every operation from raw metals to finished product within their one plant. *National Erie Corp.*

895. Castings, Nonferrous
New 16-page catalog describing nonferrous castings and metal pattern operations. Covering such subjects as magnesium and aluminum alloys; polishing of aluminum; examples of good castings; copper-base alloys; and other pertinent information on production. *R. C. Wellman & Assoc.*

896. Combustible Recorder
New 16-page bulletin shows design improvements for the Bailey combustible recorder with illustrations of typical applications for industrial furnaces. *Bailey Meter Co.*

897. Combustion Safeguard
New bulletin W1816 describes application of Pyrotrol in protecting gas-fired ovens, furnaces and other industrial heat treating equipment from danger of gas explosions during ignition operation and shut-off. *Bristol Co.*

898. Combustion Tubes
Zircam combustion tubes recommended for all types of work requiring gas-tight tubes for temperatures up to 2900° F. Described in bulletin 214. *Burrell Corp.*

899. Corrosion, Piping
New bulletin 485 on "Corrosion Service Piping" is a comprehensive treatment on stainless steel in nickel-alloy anti-corrosion and anti-contamination piping. This illustrated book discusses economics, standards, advantages of welding, extensive technical data, design tips, and complete dimensional information on stainless fittings and flanges. *Taylor Forge & Pipe Works.*

900. Cutting Oils
For the right combination to suit your specific requirements, write for the booklet, "Cutting Fluids for Better Machining". *D. A. Stuart Oil Co.*

901. Electric Heater
An almost endless variety of standard electric heating units, many entirely new, are listed in the new Chromalox catalog of industrial electric heaters. *Edwin L. Wiegand Co.*

902. Electrodes
Booklets EW-141 and EW-137, an electrode catalog and welder catalog, showing complete lines of arc welding electrodes and AC and DC arc welders. *The Hobart Brothers Co.*

903. Electrodes, Low Hydrogen
Booklet 1249 gives specific information on the use of low hydrogen electrodes for welding low alloy cast steels and high tensile strength rolled steels; high carbon steels, high carbon to mild steels and free machining steels. *Arcos Corp.*

904. Extrusions
"Alcoa Aluminum Impact Extrusions" is the title of a new booklet giving up-to-date information on short-cuts to designing all types of parts by means of these new impact extrusion presses. *Aluminum Co. of America.*

905. Finishes
Bulletin 1400 tells how the new Hydro-Finish provides cleaner, smoother surfaces prior to coating processes; saves hours on the production line. *Pangborn Corp.*

906. Furnace
New brochure describes batch-type controlled atmosphere furnace in actual plant operation, including charts showing uniformity of gas-cyanided case depths obtained and typical operating cost breakdowns for light case parts. *Dow Furnace Co.*

907. Furnaces
Attractive new bulletin, "Cyaniding in Continuous and Batch-Type Furnaces", describes new applications in dry cyaniding. Ask for bulletin SC-145. *Surface Combustion Corp.*

908. Furnaces
New 72-page bulletin No. 116 describes electric salt bath furnaces and their many uses in hardening, annealing, brazing, tempering, quenching, etc. *Ajax Electrothermic Corp.*

909. Furnaces
New catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and elimination of skew shapes. *American Bridge Co.*

910. Furnaces
For full information on uniform, low-cost operation, write for bulletin 461. It illustrates 17 sizes and types with brief descriptions of each. *Electric Furnace Co.*

911. Furnaces
New 4-page booklet 710 stresses the importance of efficient furnace combustion and describes practical, simple way the CO_2 analyzer measures CO_2 content of flue gases to help the air supply at an optimum level. *Charles Engelhard, Inc.*

912. Furnaces
Reprints of photographs of a recent installation for heat treating austenitic manganese castings. Series 1080-1, 2 and 3 include three views of a five-ton car bottom furnace with hydraulic side dump and motor-operated rack, capable of a one-minute cycle — furnace to quench. *George J. Hagan Co.*

913. Furnaces
An all-purpose furnace with temperature uniformity for hardening and drawing operations on large parts is fully described in bulletin HD 341. *Hevi Duty Electric Co.*

914. Furnaces, Melting
Full details on the Moore Rapid Lectromelt furnaces supplied in capacities ranging from 250 pounds to 100 tons, described in Lectromelt catalog. *Pittsburgh Lectromelt Furnace Corp.*

915. Galvanite Handbook
A new 12-page, illustrated handbook explaining the uses, manufacture, and advantages of Galvanite, a special hot-dip, zinc-coated steel produced by this company. *Sharon Steel Corp.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

916. Gray Iron

Mechanical and engineering characteristics of gray iron, with details for designing cast components, all combined in new booklet furnished on request. *Gray Iron Founders' Society.*

917. Hardness Tester

New portable hardness tester with 2-inch throat capacity for greater range now available. Write for booklet with full description. *Ames Precision Machine Works.*

918. Heat Treating

Form 7340 C, an 8-page illustrated article, contains interesting story of the conveyorized harden, quench and draw installation at American Fort Pitt Spring Division. *Sunbeam Stewart Industrial Furnace Div.*

919. Heat Treating

Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

920. Machine Design

Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction." *Climax Molybdenum Co.*

921. Metal Coatings

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

922. Metal Forming

4-page leaflet describes Marform, a unique new process of precision metal forming for alloy steel, copper, brass and other metals. *Glenn L. Martin Co.*

923. Microhardness Tester

Descriptive leaflet on MH microhardness indenter, a new instrument for measuring hardness of microconstituents, fine wire, metallic foils, electrodeposited coatings, etc. Adaptable to table microscopes, simple to operate and low in cost. *Erb & Gray.*

924. Microscopes

Illustrated data sheets describing S-129 pocket microscope (40 to 60 power), the S-152 Handiscope (20 power), and the S-42 Magniprox desk magnifier. *Buhl Optical Co.*

925. Oils, Quenching

Interesting booklet describes many advantages of various quenching oils developed for uniform hardness in heat treating, higher viscosity where oil remains abnormally hot, and longer service life. *Sun Oil Co.*

926. Oils, Quenching

Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett.*

927. Optical Glass

New bulletin E-30 discusses the physical and chemical properties of optical glass. This book also contains general data on optical glass products. *Bausch & Lomb Optical Co.*

928. Pack-Hardening and Isolating Pastes

An attractive bulletin describes Carburit, the perfect solution to selective hardening problems, requiring no furnace. Also describes the new easy-to-use isolating paste, Isopac, that keeps desired sections soft when hardening in box, salt bath or other methods. *Denfis Chemical Labs.*

929. Plating

Smooth plating and advantages of Unichrome Copper are discussed in informative bulletin. *United Chromium, Inc.*

930. Polishing

New booklet, "Polishing Cloth and Abrasives", furnishes first-hand descriptions and classification of some of the most used but least described accessories in modern sample preparation. *Buehler, Ltd.*

931. Polishing and Buffing

New booklet describes polishing and buffing processes with power-operated brushes for industrial use. *Osborn Mfg. Co.*

932. Polishing Machinery

Catalog 60 illustrates complete line of polishing, buffing, grinding and deburring machinery. *Hammond Machinery Builders, Inc.*

933. Powder Metallurgy

New 36-page booklet entitled "Powder Metallurgy Today" discusses the processes, applications, characteristics and design of powder metal parts in modern industry. *F. J. Stokes Machine Co.*

934. Presses

16-page bulletin contains complete catalog information and specifications on the line of heavy duty autofed presses. *Danley Machine Specialties.*

935. Presses

Valuable reference catalog 949 contains 60 pages of important information on pressure vessels, styles and types and other handbook material. Sent upon request on company letterhead. *Hydraulic Pressing & Forging Co.*

936. Process Equipment

New 36-page book lists the company's products and activities in process engineering from complete plants to individual machines. Catalog includes grinding, mixing, classifying, processing, heat exchange equipment, hydrogenating, gas absorbing, and many other units. *Patterson Foundry & Machine Co.*

937. Products and Processes

New booklet entitled "Products and Processes" outlines the principal activities of the major corporation groups, including: alloys and metals; chemicals; electrodes, carbons and batteries; and industrial gases and carbides. *Union Carbide & Carbon Corp.*

938. Refractories

New catalog entitled "Leco Zircon Refractory Ware" lists and describes zircon-base refractory products offered. *Laboratory Equipment Co.*

939. Rods and Electrodes

Bulletin CC-3 contains chart listing each of Amsco's welding rods and electrodes and indicates the type of service for which each is designed. *American Manganese Steel Div.*

940. Rust Preventives

8-page bulletin entitled "New All-Star Line-Up of Rust Preventives" describes and lists the many uses for each of the 11 Rust Veto products developed by this firm. *E. F. Houghton & Co.*

941. Salt Baths

Technical data sheets are now available on Aerocarb and Aerocase for liquid carburizing and Aeroheat for salt-bath hardening of alloy steels. *American Cyanamid Co.*

942. Salts

New manual contains more than 70 pages of material on heat treatment with molten salt baths. Fully illustrated. *E. I. duPont de Nemours & Co., Inc.*

943. Saws

Complete blade service for metal sawing is described in Marvel Saw Blade catalog. *Armstrong-Blum Mfg. Co.*

944. Shape Cutter

A new 10-page bulletin describing low-priced portable shape-cutting machine Airco No. 3 Monograph. This illustrated booklet covers in detail the various features of this unique oxy-acetylene shape-cutting machine. *Air Reduction Sales Co.*

945. Steel, Zinc-Coated

Fully illustrated booklet, "Armco Zincgrip-Paintgrip", tells how this special-purpose steel sheet furnishes high corrosion resistance as well as stretch quality for sharp bends or flat parts of fabricated products. *Armco Steel Corp.*

946. Strain Gages

12-page catalog, on Baldwin SR-4 bonded resistance wire strain gages, is illustrated by line drawings distinguishing 11 types of gages and listing 102 standard models. *Baldwin Locomotive Works.*

947. Tempilstiks

"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, is furnished on request. *Claud S. Gordon Co.*

948. Testing

Bulletin 37 describes dependable qualities of Electromatic testing machines equipped with electronic high magnification recorder. *Tinius Olsen Testing Machine Co.*

949. Tubing

New 24-page manual contains useful data on stainless steel tubular products, including physical properties, fabricating data, corrosion resistance, etc. *Peter A. Frasse & Co., Inc.*

950. Twist Drills

New 48-page pocket size catalog on a recently introduced line of high speed twist drills and reamers covers all standard sizes and types as well as a wide range of other special-purpose drills and reamers. *Chas. H. Besly & Co.*

951. Vacuum Metallurgy

Bulletin entitled "National Research Corp. and Vacuum Metallurgy" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and development facilities and services available to the metallurgist. *National Research Corp.*

952. Vibration Control

Typical equipment installations calling for highly efficient vibration, shock and noise isolation are illustrated in this new 4-page bulletin LK551. *Korfund Co.*

953. Waste Control

Bulletin ND44-96-708 contains numerous illustrations explaining in simple terms the benefits of Micromax pH control in "Effective Neutralization of Industrial Wastes". *Leeds & Northrup Co.*

954. Welding, Arc

Descriptive data on M & T welding machines to be combined with select "70" electrodes for top-notch arc welding. *Metal & Thermit Corp.*

955. Welding Bronze

How to save material by bronze welding, an ideal combination for repair welding, building up worn surfaces and production welding, described in new 17th edition of B-13. *American Brass Co.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

November, 1949

859	879	899	919	939
860	880	900	920	940
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874	894	914	934	954
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877	897	917	937	
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IT PAYS to keep a stock of "National" carbon brick on hand to be ready for any emergency...or to handle routine repairs smoothly and efficiently. You can now get "National" carbon brick in the new 13½" size, weighing only 14.4 pounds ... *other sizes available for your particular requirements.* Carbon bricks are 20% to 45% lighter than the same sized ceramic bricks, yet do a better job in many ways. Here are some of the advantages of using "National" carbon bricks in blast-furnaces, runout-troughs, and other locations:

- NO MELTING POINT OR SOFTENING POINT
- HIGH RESISTANCE TO SLAG ATTACK
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- MORE ECONOMICAL TO USE

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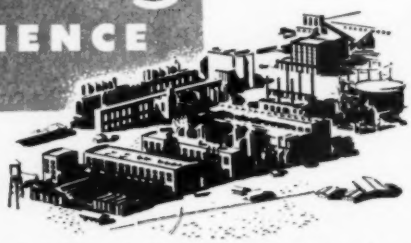

BARRETT Standard Anhydrous Ammonia was first manufactured in 1890. During the last 59 years, its dependable quality, consistent purity and uniform dryness have made it America's leading source of NH_3.

Barrett Standard Anhydrous Ammonia (*Refrigeration Grade*) contains 99.95% NH_3 and is oxygen free with a very low dew point. When dissociated, each pound produces approximately 34 cubic feet of hydrogen and 11 cubic feet of nitrogen.

Metallurgists are effecting real economies by using dissociated ammonia in the production of controlled atmospheres in furnaces for bright annealing, clean hardening, copper brazing, sintering, reduction of metallic oxides, atomic hydrogen welding, radio tube sealing and other metal-treating practices. Anhydrous ammonia also has unsurpassed qualities in nitriding of steel, used as ammonia gas or dissociated.

Barrett Standard Anhydrous Ammonia is available in 150, 100 and 50-pound cylinders from stock points conveniently located from coast to coast; or, for larger users, in tank car shipments from Hopewell, Virginia, and South Point, Ohio.

When you choose Barrett Standard Anhydrous Ammonia to supply your NH_3 needs, you are using a product which is backed by 59 years of experience. The advice and help of Barrett technical men are available to Barrett customers without charge. Free literature will be mailed on request.

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Openhearth

(Continued from p. 701)

Use of Oxygen—A round-table discussion on the economics of the use of oxygen brought forth numerous comments. Vernon W. Jones of the Armco Steel Corp. stated that he has not yet been able, from his experience, to put a monetary value on the use of oxygen in the openhearth. In general, the principal comments contained in *Metal Progress* Editor's "Critical Points" two years ago were verified. The main present use for oxygen in the openhearth is as a tool in obtaining higher temperature and for decarburization of the bath. Oxygen for fuel enrichment has been abandoned in several shops. However, Wheeling Steel Co.'s furnaces are all on oxygen combustion and it was reported that the condition of the checkers does not appear to be different from that expected for a similar campaign with no admixed oxygen during combustion. Other comments on oxygen-enriched fuel were concerned with the fact that the silica roof should be well seasoned; at least 30 heats with the roof prior to the use of oxygen is reported as good practice with 145-ton furnaces. Oxygen must be very carefully controlled when used for combustion; otherwise the roof may be seriously harmed.

Several shops have placed restrictions on the indiscriminate use of oxygen, as for example, ridge cutting in front of the tap hole. It is recognized, however, that the intelligent use of oxygen can be of great benefit when the melter is confronted with a slow, hard tap.

Further discussion on oxygen for decarburization of the bath emphasized its value for removing carbon on heats of strip steel. One operator reported a 40-min. gain per heat, equivalent to 0.8 ton per hr. or 6%, as compared with operations a year ago. However, he was still trying to evaluate the economics of the over-all program.

British Use of Basic Refractories—W. S. Debenham, Carnegie-Illinois Steel Corp., presented a paper on the use of basic refractories in England and Sweden in which he noted that the development of dolomitic refractories has figured very largely in British steel production. The availability, quality and price in England are such that magnesite cannot be used as a refractory at the present time.

(Continued on p. 724)

ARTHUR L. LaMASTERS
Champaign, Illinois

WM. H. DAVIS
Champaign, Illinois

YOUR ACCOLOY ENGINEERS *say* *"THANKS AGAIN"*

to our many friends and visitors who took time out to visit our exhibit of HI-TEMPERATURE tooling at the National Metal Show. We appreciated the opportunity of telling you something about the ADVANCE CASTING METHODS which we have developed as a result of several years' RESEARCH and DEVELOPMENT work aimed at GRAIN SIZE CONTROL of austenitic alloys. The castings which we had on display were only a small part of the ACCOLOY line of JOB PROVEN and ENGINEERED castings for HI-TEMPERATURE applications.

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Remember . . . there is an ACCOLOY engineer near you who has been trained and educated in the fundamentals of HI-TEMPERATURE designing. Many of them have installed and successfully operated Heat Treat departments. Their approach to a problem is not that of a Foundryman. If you have a HI-TEMPERATURE tooling problem, call an ACCOLOY ENGINEER. There is no obligation on your part.

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

If you did not receive a reprint of "ADVANCE CASTING METHODS", we will mail you one on request.

ALLOY ENGINEERING AND CASTING COMPANY

Alloy Casting Co. (Division)

Champaign, Illinois

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Are You Paying Too Much for Precision?

You can cut labor costs, reduce scrap, and maintain closer tolerances with the

NEW AO OPTICAL PROJECTION COMPARATOR

Here is an instrument so advanced in accuracy and convenience that it opens new possibilities for optical projection comparison in parts inspection and tool and gage measurement. Developed by one of America's most respected builders of scientific optical instruments, the AO Comparator offers many long-sought features:

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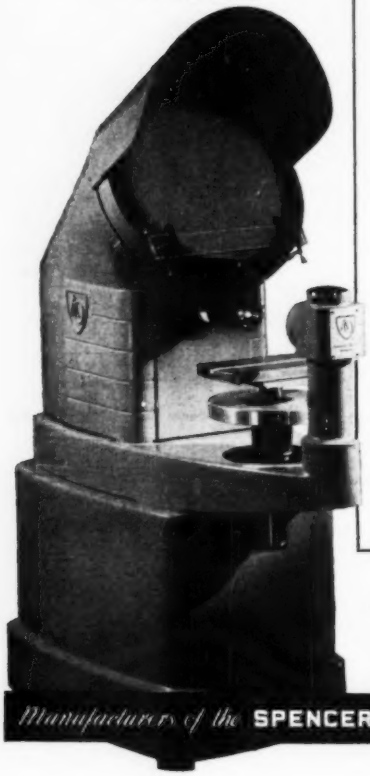

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COMPANY
Scientific Instrument Division
Buffalo 15, New York

Manufacturers of the SPENCER *Scientific Instruments*

Openhearth

(Starts on p. 701)

Both stabilized dolomite brick (made by firing a dolomite and serpentine mixture) and semi-stabilized dolomite brick are used. The semi-stabilized product is made by firing a mixture of dolomite plus 6% tar at 2550° F. and subsequently boiling the brick in tar. It has better resistance to spalling than the fully stabilized brick; the latter is reported to be very sensitive to thermal shock. In the production of the stabilized brick, the aim is to form a tricalcium silicate bond which is not susceptible to disintegration (as would be the case if the bond were dicalcium silicate).

The use of "Crespi" bottoms for basic electric furnaces was mentioned. In these, burnt dolomite (rice to dust size) and fine graphite are rammed dry. The graphite is added to improve thermal and electrical conductivity. Such a bottom requires a 20-hr. heating and drying period.

A typical British openhearth bottom, as described by Mr. Debenham, consists of three courses of flat brick, followed by four courses of stabilized dolomite brick, followed by 9 in. of tarred dolomite. The reported life of such a bottom is two to four years.

Two all-basic openhearth furnaces at the Redmond plant of the Richard Thomas Works were also described. One had a sprung basic roof which went 289 heats before falling in. When a basic roof gets under 6 in. in thickness, it is considered unstable, and for best results a suspended type of roof is necessary. (The all-basic openhearth furnaces of 35 to 70 tons capacity, cold charged, which are common in Sweden have utilized both "Radex"* and American magnesite brick, which rated very close in performance. Roof life of 1000 up to 2300 heats is reported.

One additional comment was the fact that British investigations on gas flow in openhearth furnaces make use of model furnaces. These, together with fundamental studies on fluid flow and aerodynamics as they are related to gas flow in the entire system, have as their objective a better furnace design for more efficient use of fuel.

(Continued on p. 726)

*For description of this brick and many other details of European practice see the extensive article by Pierre Bettembourg in *Metal Progress* for September 1947, p. 403.

Photos courtesy of:
1 and 2: American Gas Furnace Co.
3: York Corporation
4: The Fafnir Bearing Co.
5: The Union Fork & Hoe Co.

This is what we mean: Furnace parts and fixtures made of D-H cast alloys, such as Nichrome* and Chromax*, give top-level performance and *stay on the job* despite punishing cycles and high rate quenching . . . because exclusive Driver-Harris techniques endow these alloys with heat and corrosion-resistant properties that assure exceptional efficiency, long life and dependable service under the toughest conditions.

That is why, in hundreds of plants from coast to coast, you find D-H castings still on the job after thousands of hours of operation.

Take examples such as these:

1. In rotary gas carburizers such as this, large Nichrome retorts (averaging 1,800 pounds of work) have served up to 24,000 hours apiece at temperatures approximating 1600°F.

2. In this vertical carburizing furnace, operated at 1650°F., a Nichrome retort of 30" inside diameter has given 36,000 hours of trouble-free service.

3. The Nichrome baskets and fixtures shown here, used for hardening stainless steel impeller blades, "stand the gaff" for years—despite punishing cycles that include heating to 1825°F. and exceptionally high rate quenching.

4. In this annealing furnace for forged ball bearing rings, one of a battery of 14 operated at nearly 1500°F., cast Chromax baskets carry the work, furnace elements of Nichrome strip supply the electric heat. Continuously subjected to heating and cooling, the baskets stay on the job 6-8 years without need of repair; the heating elements give top-level performance for 15-20 years.

5. This 1450-pound Nichrome pot, holding 2 tons of molten lead, acted as heating medium for shovels and forks during hardening operations (at 1550°F.) for over 26,000 hours before being removed from the furnace.

Outstanding benefit of service such as this is the *paramount* advantage of *low heat-hour costs*.

Whatever *your* heat-treating problems you'll find D-H alloys unsurpassed for conventional applications, indispensable if particularly exacting requirements must be met. So consult with us. The fruits of our nearly 50 years of experience are at your service.

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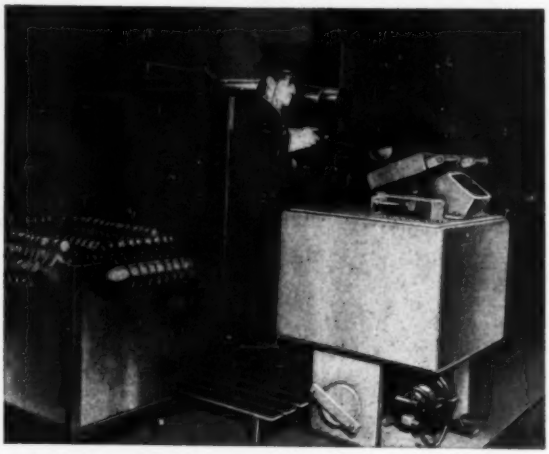
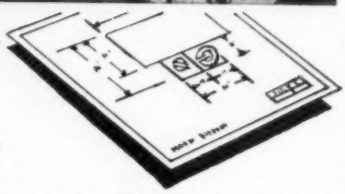
WITH AJAX TAMA-WYATT

INDUCTION FURNACES for Aluminum Alloys



Ajax Induction Holding Furnace at Mid Western Die Casting Co., Chicago, Illinois



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Associate Companies: AJAX METAL COMPANY, AJAX ELECTROTHERMIC CORP., AJAX ELECTRIC CO., INC., AJAX ELECTRIC FURNACE CORP.

Openhearth

(Starts on p. 701)

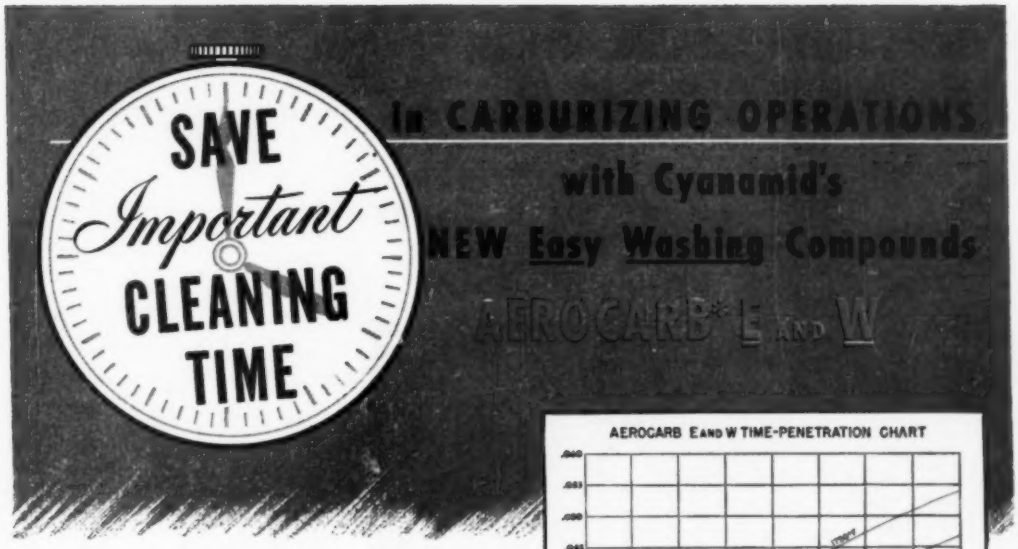
Sulphur Control in Hot Metal— In a paper concerned with the effect of the sulphur contained in the coke on the iron's content, A. W. Thornton of National Tube Co. cited the results of a detailed study of limestone-dolomite flux on the removal of sulphur from the hot metal. Although the author stated that there remains coal for many generations to come, there are already instances of a serious scarcity of low-sulphur metallurgical fuel. Likewise, over the past years the sulphur content of coke has steadily risen. For example, average sulphur values for coke were 0.86% in 1944 and 1.50% in 1948!

The investigations reported had as their aim the determination of the most effective range of slag compositions for the economical removal of sulphur. Slag compositions were altered during these experimental runs by varying the amount of dolomite and limestone in the flux charge. Average analyses of the dolomite and limestone used were:

	CaO	MgO
Dolomite	30.36%	21.11%
Limestone	52.55%	0.64%

The flux charges were composed of *(a)* 100% limestone, *(b)* 35% dolomite and 65% limestone, *(c)* 70% dolomite and 30% limestone, and *(d)* 100% dolomite. A blast furnace, operating with 100% Mesabi ore and beehive coke and producing bessemer hot metal, was utilized. Sulphur in coke varied from a low of 0.95% to a maximum of 1.06%. The lowest sulphur iron (0.018%) was produced with 35% dolomite, 65% limestone flux practice, and the highest sulphur iron (0.027%) occurred when the flux composition was 100% dolomite. The 35% dolomite flux series showed higher sulphur ratios (% S in slag to % S in iron) and were the highest when the slag basicity $\left(\frac{\%\ CaO + \%\ MgO}{\%\ SiO_2}\right)$ was above an average of 1.49. Higher sulphur ratios were favorably affected by flush slag temperatures above 2760° F. and a silicon content in the iron of above 1.49%. Statistical studies of the data showed the best range of sulphur ratios (100 to 120) when the previously mentioned factors of slag basicity, flush slag temperature and silicon content of the iron were above the values

(Continued on p. 728)



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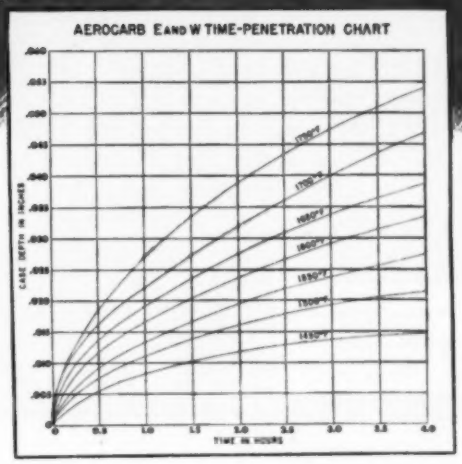

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SPERRY

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DANBURY, CONNECTICUT

Openhearth

(Starts on p. 701)

noted for the 35% dolomite plus 65% limestone flux.

It was concluded that up to an optimum level of somewhere between 5 and 8% of MgO in the slag (35% dolomite) desulphurization of the iron is improved. The favorable results obtained through the use of dolomite in this range indicate its practical value for combating an increasing sulphur content in the raw materials. Increased MgO beyond this range had an adverse effect on desulphurization, since it required more flux with a consequent increase in slag volume and coke rate.

Conservation of Manganese, judging by the amount of discussion, appeared to be a matter of major interest. The keynote was expressed by C. E. Sims of Battelle Memorial Institute, chairman of the session: "We should see how wisely manganese can be used in steelmaking, rather than how little manganese can be used." The necessity for doing just that was pointed up by an observation by J. C. Vignos of Ohio Ferro Alloys Corp., that, early in 1949, the amount of imported manganese ore was cut 40%, a situation made tolerable only by a falling off in steel production. In subsequent discussion of this point, O. C. Ralston of U. S. Bureau of Mines stated that at present manganese ore is regarded as the "No. 1 mineral problem" by the government officials. Token shipments of manganese ore may be expected from Russia, but reliable sources are obviously necessary.

Among other points discussed by Mr. Vignos were the following:

I — Methods for Conservation:

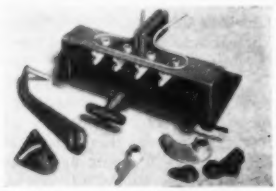
(a) Recycling of openhearth slags in the blast furnace. Some 70% of the manganese can be recovered in this way. However, all the phosphorus from the slag is likewise recovered, and this limits the slag which can be recycled.

(b) Cutting down on the volume or eliminating the flush-off slag, which causes large losses of manganese. Lower silicon pig iron (hot metal to openhearth) would minimize manganese losses. If the iron has less than 0.50% silicon, the flush-off slag could be eliminated. Smaller additions of hot metal to the furnace would also aid.

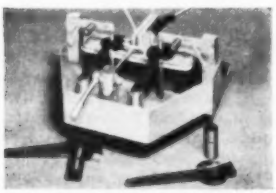
(c) Improvement of subsequent manganese recovery by a higher silicon residual after blocking.

(Continued on p. 730)

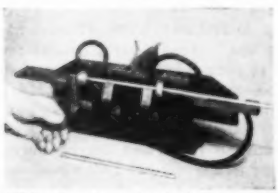
This fixture brazes caps on seamless tubing to form 200 dashpots per hour, at 1/5 the previous cost. They were formerly deep drawn.



Bushings are brazed on six different cam assemblies and crank arms with this fixture—production rate 160 per hour.



This water bath fixture brazes the hollow shaft to the arm without annealing the hardened key on the end of the shaft, at 200 per hour.



This fixture selectively anneals three points—later drilled—on a hardened shaft at 800 per hour. Two different shafts are handled by adjusting the coil positions.

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3. **Elimination of detailed inspection, formerly required**
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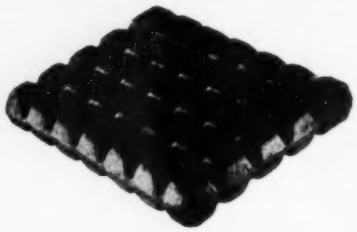

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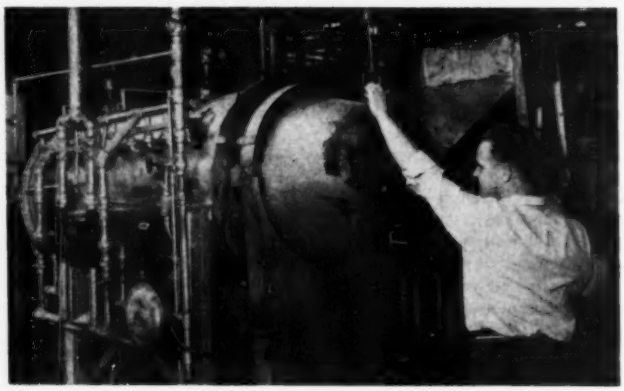

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Openhearth

(Starts on p. 701)

(d) Additions of manganese in the ladle whenever possible — recovery will be some 10% better than for furnace additions.

(e) Addition of fine ferrosilicon to the tapping stream before the stream breaks. A 4 to 6% better recovery of manganese added in the furnace will result from this practice; it also lessens the amount of oxidation in pouring.

II — Retreatment of Slag:

(a) Methods for actual treatment of basic openhearth slag which would involve first the removal of the phosphorus from the slag. The slag would then be treated with silicon to recover a low-carbon ferromanganese.

III — Concentration by Flotation:

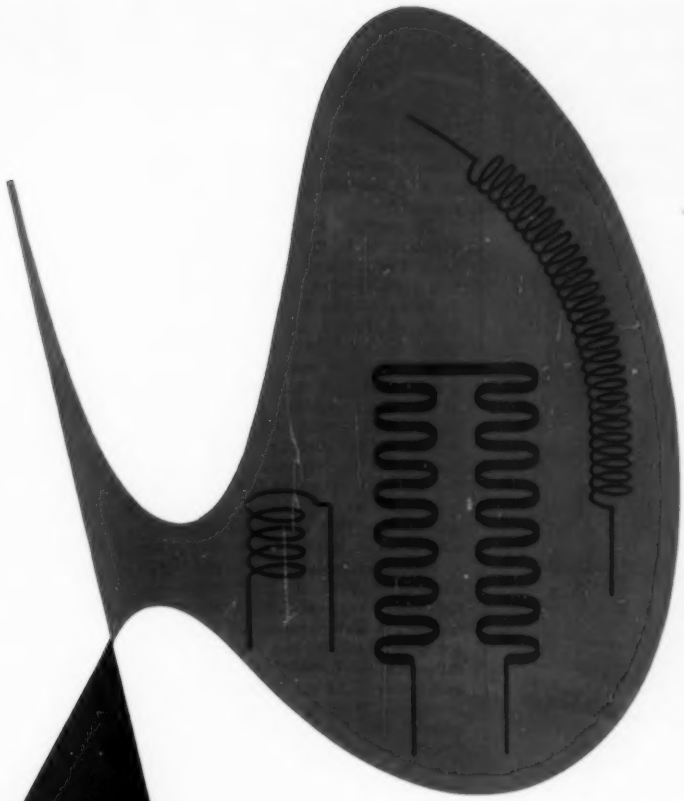
Other slag treatments proposed involved the use of a flotation process to recover an iron-manganese oxide freed from the phosphorus-bearing lime silicate fraction of the slag. Openhearth slag is composed essentially of two intimately mixed phases occurring as a eutectic aggregate; the oxide solid solution phase (Fe, Mn, Mg)O, and the phosphorus-containing dicalcium and tricalcium silicates. Slow cooling and a coarser crystallization would be required to get a better separation of these constituents. Fine grinding to free the two constituents of the slag prior to any flotation treatment would, of course, be necessary.

IV — Low Grade Ferro:

The use of ferromanganese which contains less manganese than the standard grade (78 to 82% manganese), including those ferroalloys containing 50 to 78% manganese, should be considered as a step in conservation. Down grading of standard ferromanganese, as pointed out by the recent American Iron and Steel Institute report on "Problems Involved in the Conservation of Manganese", can be of prime importance in any program for using large quantities of low-grade ore which may become available.

At full steel production capacity in the United States, openhearth slag containing 750,000 tons of manganese metal is produced. Mr. Ralston advocated the separate storage of manganiferous slags; they could then be reworked for recovery of manganese if, as and when necessary. Studies of recovery costs indicated that it may be feasible, even

(Continued on p. 732)



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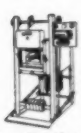

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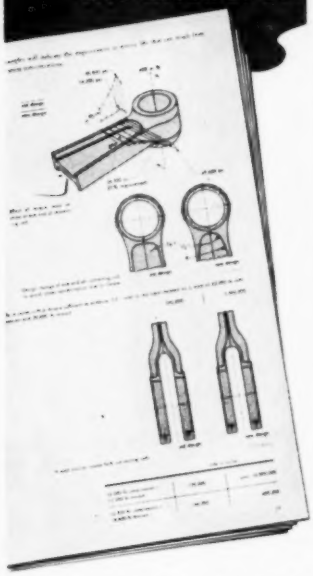

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MOLY

Openhearth

(Starts on p. 701)

within present price brackets, to rework these slags. In case of emergency the recovery of manganese from openhearth slags would be a prime means of meeting our requirements.

In further discussion of this problem, D. H. Babcock of Republic Steel Corp. emphasized the point that reduction of manganese specifications in the standard A.I.S.I. steel analyses would save only about 5% of our manganese consumption. The bulk of manganese consumed is for the lower manganese carbon grades such as strip, shapes, piling and plates. He also mentioned the direct wastage of the manganese in ferrograde ores due to a 15% volatilization loss in smelting. Recovery of half of this fume would save 10% of the manganese contained in imported ores.

Ingot Solidification — In the discussion of Prof. J. W. Spretnak's paper on "Vertical Solidification in Ingots", it was emphasized that ingot solidification has a very real influence on internal soundness, and hence is of great practical importance. Studies of ingot solidification are hampered because sampling, for one thing, is expensive. Complex influences which have not been separately evaluated — such as casting temperature, gas content, composition, segregation effects — have yet to be considered. The improvement of mold design to enhance vertical solidification (which results from heat abstraction from the bottom of the mold by both conduction and radiation) was advocated for several reasons, including the fact that a sounder ingot is produced if the vertical solidification core is wide rather than narrow and limited. The acceleration of vertical solidification at the expense of transverse solidification can result in a lower volume of hot top.

Mold Coatings and Surface Quality were discussed in some detail by J. F. Pollack of Jones & Laughlin Steel Corp. The perfect mold coating should evolve some gas at the time it contacts with the molten steel, rising in the mold to prevent foreign material and splashes from adhering to the ingot's surface. Results of an extensive investigation of tar dipped molds, pitch powder sprayed, and aluminum powder sprayed coatings, together with uncoated molds, showed that the tar

(Continued on p. 734)

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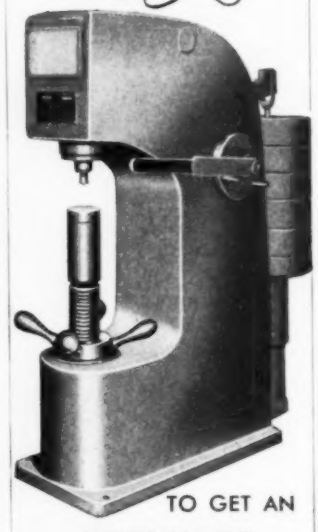

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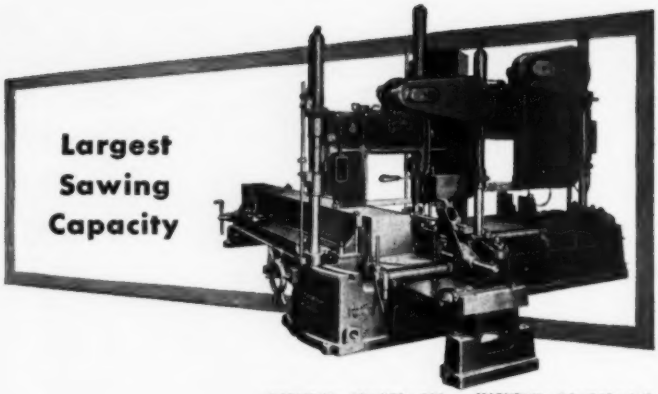

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Openhearth

(Starts on p. 701)

dipped mold coating is superior. It has some disadvantages, since it is wasteful of tar, creates considerable fumes, and constitutes a fire hazard. Substitutes are being sought but no coating has yet been found to give a superior surface quality in the subsequent ingot.

These investigations on mold coatings included molds for strip steel ingots for tin plate and for deep drawing products, as well as for fully killed ingots for bar products. Openhearth tin-plate grades inspected for bad edges, for example, showed rejects to be three times higher for ingots from uncoated molds as compared with ingots from tar dipped molds. On the scarfing bed inspection, tar dipped products were definitely superior to pitch powder sprayed. With fully killed bar products on scarfing bed inspection (comparing tar dipped, pitch sprayed, aluminum sprayed) only the aluminum sprayed product could equal the tar dipped product as to scarfing rate. The bar mill product also showed the best results for tar dipped mold coating.

Comments on this paper included the remark that the secret of good mold coating practice is to have the mold at the right temperature during the coating operation. At the present time the real reason for the superiority of tar dipped mold coatings on surface quality is not definitely known.

Soaking Pit Practice—One of the more important points mentioned in a discussion from the floor of the relationship between soaking pit practice and quality of ingot surface was that the heater should be promptly informed about heats that do not rim properly. Close cooperation between mill metallurgists and the heaters is most important, especially in circumstances where difficulty in producing the heat has previously been experienced, so as to insure proper handling of the metal through the soaking pits and subsequent rolling and heating operations.

The well-known attribute of copper in contributing to surface difficulties was discussed by O. C. Ralston of the U. S. Bureau of Mines. He mentioned a flux containing nickel oxide plus borax glass which, when applied to the surface of small experimental high-copper steel ingots, eliminated the expected surface difficulties.

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Powder Metallurgy in Germany*

TWO important contributions of powder metallurgy to the German war effort were *(a)* shell driving or rotating bands of sintered iron and *(b)* cemented carbides for tool tips and for armor piercing shot.

Sintered driving bands were originally introduced to save copper, but were eventually found to have certain ballistic advantages and to wear the gun barrel less. Its importance may be judged by the fact that, at the peak of production in October 1944, 3500 tons of iron powder were produced, 93% of which went into the manufacture of driving or shell rotating bands. The total production of bands of all sizes during the war is estimated at one billion pieces.

Originally, all powder for shell bands was manufactured (by the "Hametag" process developed before the war) by the attrition of mild steel wire cuttings in a water-cooled cast iron mill through the action of rotating steel hammers. Such powder is particularly suited for pressing and sintering, but is rather expensive. Two new processes for powder production were therefore developed by the Germans during the war. In the "D.P.G. Disk-Atomizing" process, molten mild steel or low-silicon cast iron is poured through a nozzle into the apex of a water cone. The resulting particles are further distorted by impact with fast revolving stainless steel blades. In the "R-Z" process, the second war development, molten pig iron is atomized with compressed air using a special cyclone nozzle. The oxygen content introduced during atomization and the carbon content remaining in the atomized product are controlled so that they react during a subsequent annealing operation, and are removed as carbon monoxide.

Both the "D.P.G." and the "R-Z" processes presented considerable difficulties in production, troubles which persisted up to the end of the war, and which impaired the quality of the powders so that they were not used alone for making shell bands, but were mixed with at least an equal weight of Hametag

(Continued on page 738)

*Abstract of "Powder Metallurgy in Germany During the Period 1939-1945", by R. A. Hetzig; British Intelligence Objectives Sub-committee Overall Report No. 20; His Majesty's Stationery Office, London, 1949.

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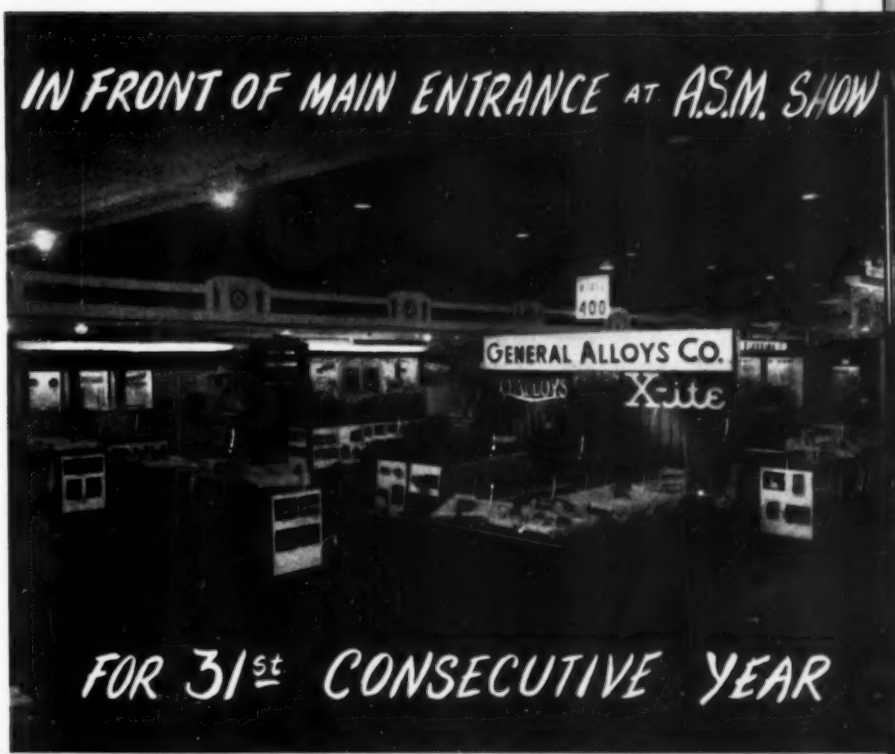

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Powder Metallurgy in Germany

(Continued from page 736)

powder. Production processes for bands were rigidly standardized by control of powder characteristics, green densities, and the tensile strength, elongation and wax absorption of sintered bands.

Cemented carbide tool tips were held virtually indispensable by the German war industry. Their output reached about 600 tons in 1944 in spite of a serious tungsten shortage which reduced the yearly output of cemented carbide armor piercing bullets from 682 tons in 1940 to 173 tons in 1943. Production of carbides was largely concentrated at the Krupp works; special techniques were developed to expedite production, such as rotary tube furnaces for the reduction of oxides, and vibrating ball mills for mixing powders. A new press for fast hot-pressing was Krupp's outstanding achievement in the carbide field.

German attempts to develop tungsten-free hard metal tool tips were rather unsatisfactory, although a 45% VC, 45% TiC, 10% Ni grade was manufactured by Krupp.

The report cited also contains an extensive bibliography of available British and American Government reports and foreign documents on powder metallurgy in Germany.

High-Current Arcs*

ONE of the most useful metal-joining processes being applied today is arc welding. In the development of modern arc-welding processes and welding materials, an adequate understanding of the mechanism of the welding arc is most desirable. Since welding arcs are essentially of the high-current variety this explanation by Wolfgang Finkelnburg of the high-current carbon-arc phenomena is of considerable interest to the welding industry, as well as to physicists and chemists.

The high-current carbon arc is operated with anodic current densities between 100 and 400 amp. per sq.cm., compared with approximately 40 amp. per sq.cm. for the low-current arc. In the high-current

(Continued on page 740)

*Abstracted from "The High-Current Carbon Arc and Its Mechanism", by Wolfgang Finkelnburg, *Journal of Applied Physics*, Vol. 20, May 1949, p. 468-474.

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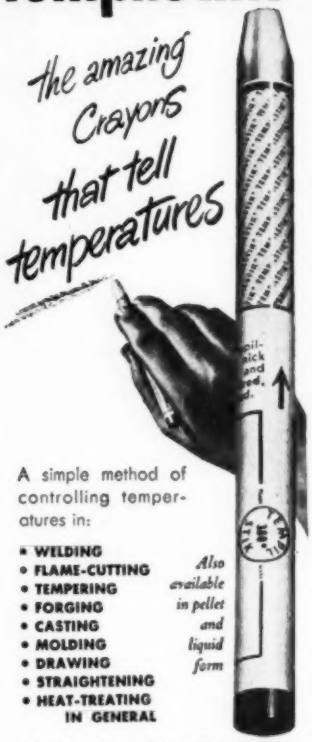

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188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
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High-Current Arcs

(Continued from page 738)

carbon arc the behavior of matter and its reactions at temperatures between 6000 and 12,000° K. (abs. temp.) can be studied and it is the only easily accessible source of such temperatures.

Because of the high current density and relatively large anodic voltage drop, a comparatively large consumption of the positive carbon occurs in the high-current arc. This consumption ranges from 10 to 50 in. per hr., compared with an average of 3 to 4 in. per hr. for the low-current arc. In the high-current arc carbon consumption is due to evaporation, whereas in the low-current arc it is due to combustion. This rapid evaporation in the high-current arc produces the deeply molded crater in the hot core and fills this crater with brightly radiating vapors which are ejected from the crater to form the vapor flame, a characteristic of this type of arc. Whereas, in the low-current arc only the incandescent electrode surface, 4000° K. or below, is responsible for the radiation, in the high-current arc the crater vapors, 6000 to 8000° K., are the main source of radiation.

More than 70% of the total power input of high-intensity arcs is emitted as radiation and light efficiencies range from 55 to 90 lumens per watt, compared with 23 lumens per watt for the low-current arc. These figures apply primarily to the carbon arc.

At currents above 80 amp. the normally diffuse arc stream seems to contract into a narrow bluish-white column surrounded by well-defined zones of different colors. Practically all the current passes through this column at the high current density of 1000 to 3000 amp. per sq.cm., causing there a temperature in excess of 10,000° K. In the low-current arc stream measured axial temperatures of about 6800° K. are found. The temperature of a 200-amp. arc stream is about 11,000° K., and higher temperatures would be expected for higher currents.

The transition from low to high current arc stream is explained by the author as follows: "With increased current, the arc stream can either increase its diameter at the constant temperature of 6800° K., corresponding to the minimum total heat conductivity, or it can remain at constant diameter with increased temperature and consequently with

(Continued on page 742)

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tubes

Alundum Refractory tubes are made in a variety of sizes for electric furnaces of the metal resistor type. Because of the excellent electrical qualities of Alundum the resistor can be wound directly in the tube. They are used largely in furnaces for wire drawing, particularly tungsten and molybdenum and for sintering cemented carbides. Crystolon tubes can be supplied in the same sizes for many high temperature operations where electrical insulation is not a factor. Alundum is also available as thermocouple tubing and as pyrometer tubes, both ideal, for protecting costly thermocouples in temperature recording devices.

cores

Alundum cores are very useful in furnace manufacture. They have all the properties of Alundum tubes with the added physical feature of being molded with grooves for retaining the resistor wire. For the operator who must prepare a special furnace on the job, cores are a great help because the resistor can be applied easily and simply in the spacing provided.

The resistor may be spiralled or straight and wound in the grooves and then embedded in Alundum cement. Thus, fully protected, the wire is less liable to corrode since these mixtures are chemically inert. Alundum cores have high heat conductivity and do not become electrical conductors even at high temperatures.

muffles

One-piece muffles of both Alundum and Crystolon can be provided, rectangular, "D" shape and "U" shape for building small furnaces heated by oil, gas or electricity. Such furnaces are used in a great variety of operations and most prefabricated furnaces on the market have furnace chambers formed by muffles of one or the other of these materials. Only Crystolon muffles are carried in stock, but Alundum muffles are gladly supplied on order. Alundum muffles are used primarily where electrical resistance is desired at temperatures above 1250° C. In electric furnaces the resistance wire encircling the muffle should be embedded in Alundum cement.

small furnace refractories

mixture designation	composition	structure	shapes available	remarks
RA 98*	alumina 89%	fine	cores, tubes, muffles and most special shapes	subject to reduction of silica above 1450° C. in reducing atmosphere.
RA 1139*	alumina 99%	fine	cores, tubes, muffles and many special shapes	used to 1650° C. but subject to distortion above 1550° C. under load.
RA 1192*	alumina 99-%	fine	tubes and certain flat and simple shapes	used to 1750° C. but subject to some distortion above 1600° C. under load.
RA 1213	alumina 99-%	medium	tubes, certain cores, muffles, and flat and simple shapes	used to 1900° C., little distortion in use to 1800° C.
RA 1191	alumina 99-%	coarse	tubes, certain muffles and flat shapes	used to 1900° C., little distortion to 1850° C.; coarse grained surface.
RC 217*	silicon carbide 65%	fine	cores, tubes, muffles and special shapes	reduction, oxidation and electrical conductivity increase with temperature; not recommended for use above 1100° C.; suitable for use with base metal resistors only.
RC 1138	silicon carbide 83%	medium fine	some cores, tubes, muffles and special shapes	reduction, oxidation and electrical conductivity increase with temperature; not recommended for use above 1450° C.; suitable for use with base metal resistors only.

*suitable electrically heated furnaces only.

refractory cements

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NORTON REFRACTORIES

High-Current Arcs

(Continued from page 740)

increased electric conductivity. Above currents of approximately 100 amp. the second possibility seems to be more favorable for the energy balance because of the exponential increase of the electric conductivity with temperature."

In the low-current carbon arc a certain part of the positive ions necessary to maintain a stable electric discharge is produced by ionization in the anode drop region while the rest is emitted by the anode surface due to incidence of electrons, accelerated by the anode drop. This incidence of electrons maintains the anode surface at a sufficiently high temperature for this emission. The negative space charge in the quasi-neutral arc stream causes a potential drop immediately in front of the anode surface — "anode drop".

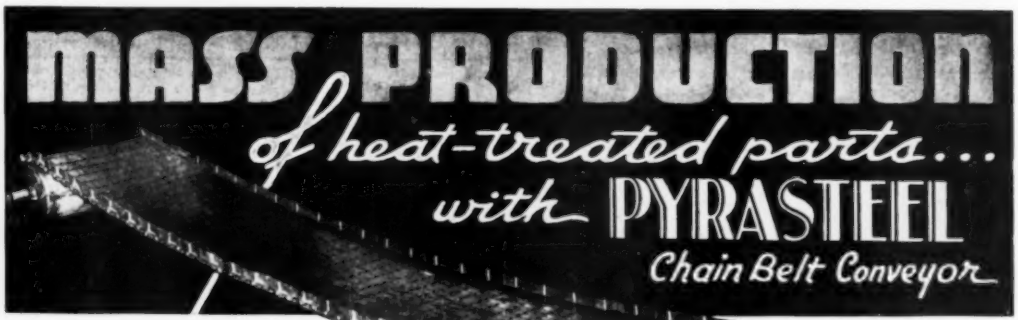
The ions which are thus produced diffuse in the electric field of the discharge toward the cathode and these ions are essential to compensate the negative space charge of electrons and produce equilibrium. If there were no anode drop to facilitate ion emission by the anode, the incident energy of bombarding electrons on the anode surface would not be sufficient to compensate for the cooling of that surface due to radiation and conduction and insufficient ion emission would occur. A certain anode drop is therefore a necessary element of the arc mechanism and it varies with the negative space charge in front of the anode surface to produce equilibrium in the discharge. The anode drop of the low-current carbon arc using a pure homogeneous positive carbon, as in welding, is approximately 30 volts.

In the high-current carbon arc the vapor stream from the anode blows ions away from the anode, resulting in an increased negative space charge in front of the anode surface, which causes an increase of the voltage drop in front of that surface. This continues until sufficient ionization, caused by electrons accelerated by the larger anode drop, establishes an equilibrium in the discharge. In this state, not only is sufficient ionization occurring in the anode drop to compensate for the ions blown away by the vapor stream, but also the accelerated electrons deliver to the anode enough energy to sustain the anodic vapor stream — the main feature of high-current arc discharges.

This explanation of the mechanism of the high-current carbon arc accounts for the characteristic "arc flame" of welding arcs.

The anodic vapor stream is affected by a magnetic field because near the anode it forms a part of the arc stream in which the electrons are mainly carrying the arc current. Any magnetic deflection of the electron stream in this region will be imparted to the vapor stream and cause an over-all change of its direction. In the absence of external magnetic fields the anodic vapor stream (arc flame) is deflected, in the direction of the bisector of the obtuse angle formed by the positive and negative carbons, by the magnetic field of the arc itself. This field exerts an outwardly directed force on the arc stream thus accounting for its curvature. At currents over about 100 amp. these effects predominate.

The influence of external magnetic fields on the anodic vapor stream discussed here is evidenced in a practical manner by the "magnetic blow" sometimes encountered in arc welding with either carbon or metal electrodes. The mechanism of the high-current arc explained here is utilized in the twin-carbon arc-welding processes.



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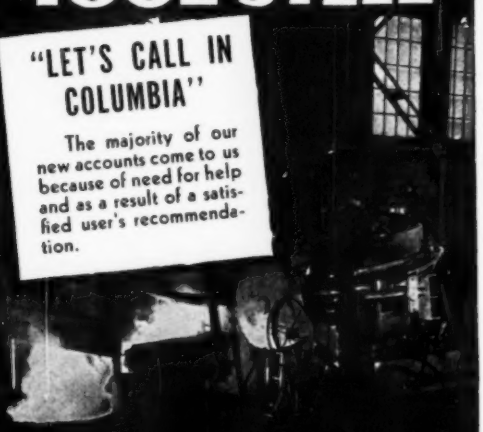

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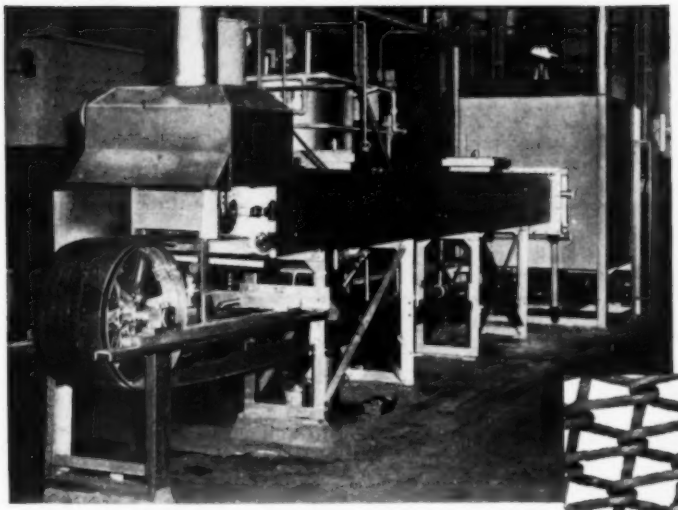

Inconel conveyor belt installed in Electric Furnace Company continuous brazing furnace at the Beech Aircraft Corp., Wichita, Kansas. This WISSCO belt woven of Inconel was manufactured by the Wickwire Spencer Steel Division of the Colorado Fuel and Iron Corporation. It has served for two and a half years, operating at temperatures as high as 2040° F.

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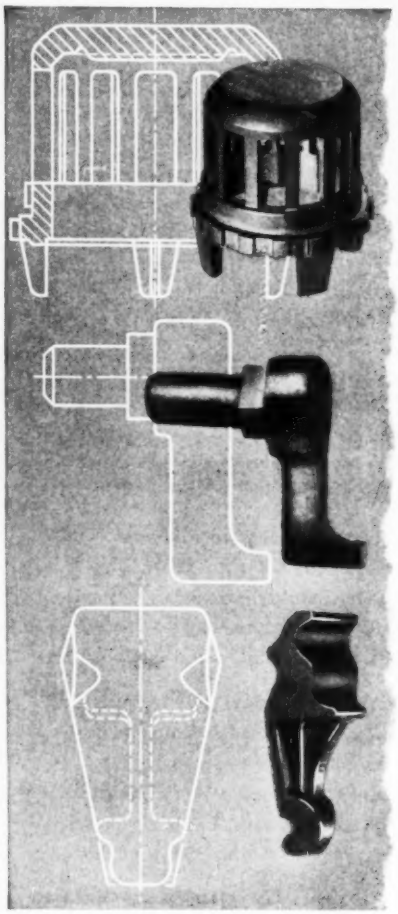

Assembly costs are eliminated by producing this stainless steel valve cage by the precision investment-casting process. Formerly made in two pieces and joined together, the cage is now produced as a single, integral casting.

This screw cycle controller is investment-cast from a one-piece wax pattern. The part was formerly made by brazing together two individual pieces machined from bar stock.

This HAYNES STELLITE alloy sealing segment was redesigned in order to avoid warpage and distortion. Although the ribbed section —which was formerly solid —adds to the intricacy of the part, it causes no fabrication difficulties when produced by HAYNES precision investment casting.

The alloys that are available as HAYNES precision investment castings—such as HAYNES STELLITE, HASTELLOY, and MULTIMET alloys, and certain stainless steels—are strong materials that resist the most severe abrasion, heat, and corrosion. But because of their unusual properties, these alloys are often difficult and costly to fabricate by conventional methods. The precision investment-casting process, however, is a practical method of producing parts from these materials. And it makes possible the liberal use of such design features as thin edges, fillets, irregular holes, and intricate contours.

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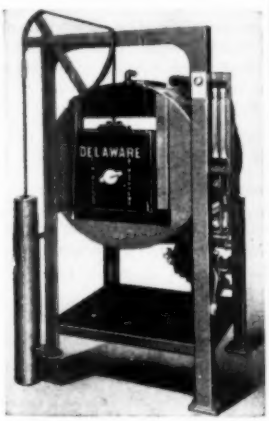

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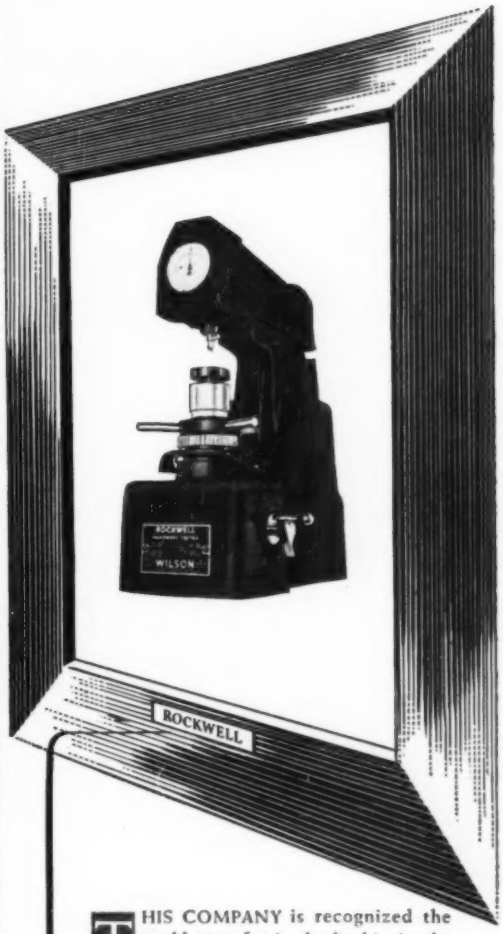

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1. The names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, American Society for Metals, 7301 Euclid Ave., Cleveland, Ohio; Editor, E. E. Thum, 7301 Euclid Ave., Cleveland, Ohio; Managing Editor, E. E. Thum, 7301 Euclid Ave., Cleveland, Ohio; Business Manager, W. H. Eisenman, 7301 Euclid Ave., Cleveland, Ohio.

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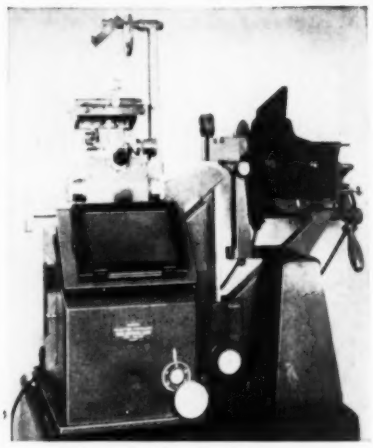

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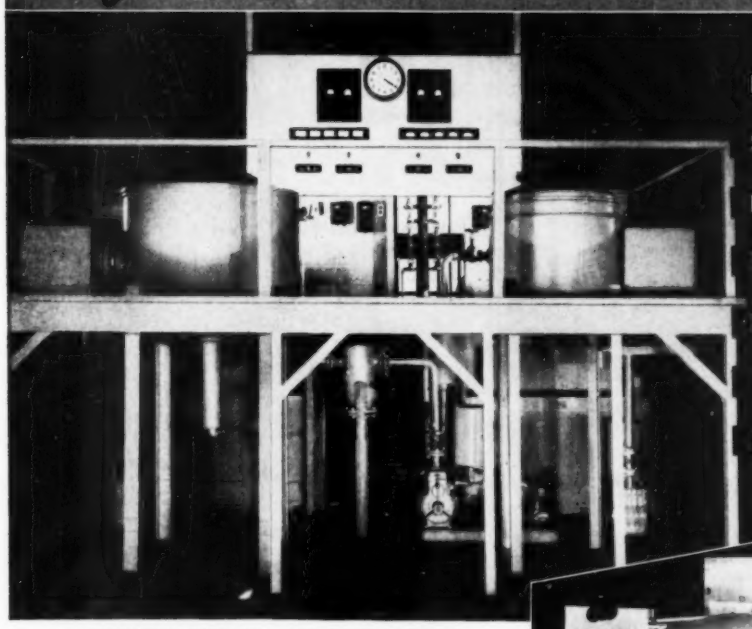

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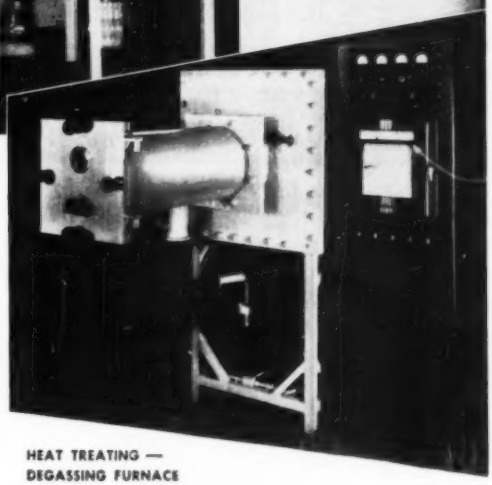

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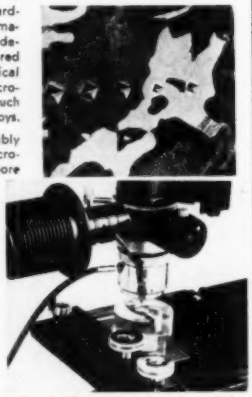

(Above) Micro-indentations in carbide and pearlite areas of cast iron specimen. Magnification 1000. (Below) MH Hardness Indenter mounted on table microscope.

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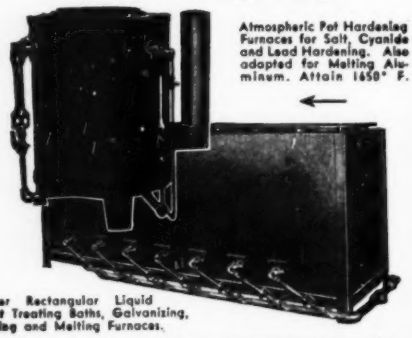

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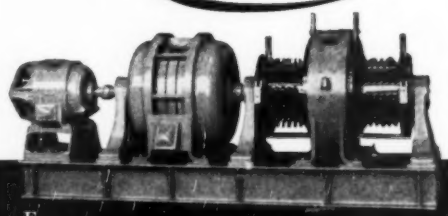

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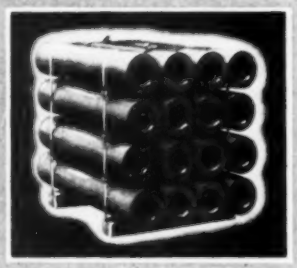

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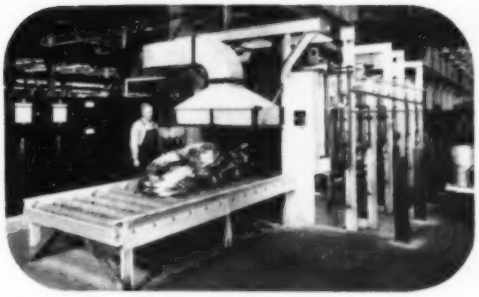

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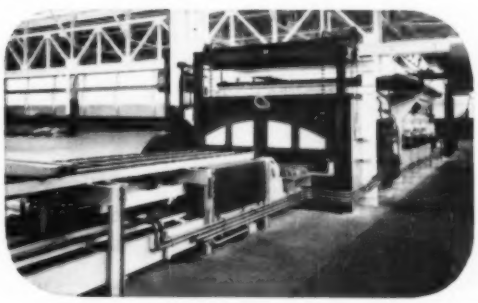

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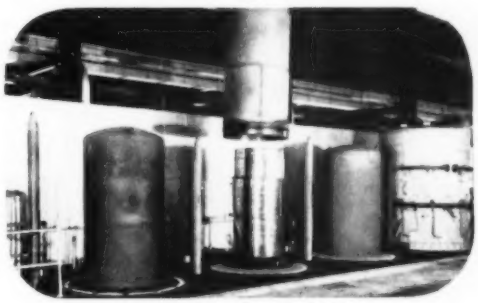

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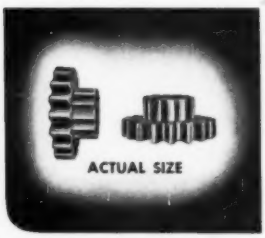

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